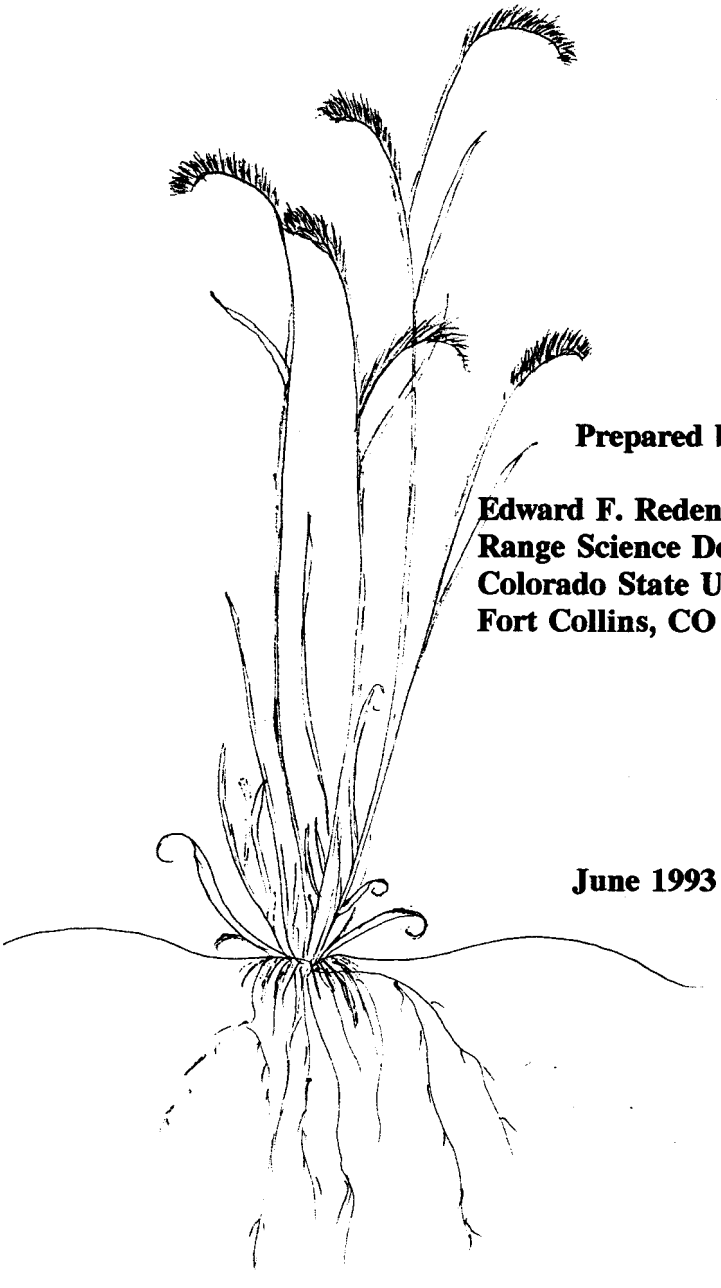
RESTORATION MANAGEMENT PLANS FOR NATIONAL PARK SERVICE PRAIRIE SITES IN COLORADO, SOUTH DAKOTA, NORTH DAKOTA, AND WYOMING



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SECTION A

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INTRODUCTION

A visit was made to Bent's Old Fort on May 13 and 14, 1992 to assess the condition of the native prairie and discuss specific issues associated with restoration work needed at the site. The following document provides specific recommendations for restoration work that is needed at Bent's Old Fort to aid in the reestablishment of native prairie in this historical area. In addition to restoration recommendations, the report includes a discussion of approaches for long-term monitoring of restoration success, recommendations for native seed collection, and suggestions for conducting a threatened and endangered plant species survey.

RESTORATION RECOMMENDATIONS FOR SPECIFIC UNIT DESIGNATIONS

Unit 2

Unit 2 is a site consisting of approximately 36 acres located north and west of the Fort. The site was subject to cultivation for an unknown period of time and an attempt was made in the 1970s to seed the area to blue grama (Bouteloua gracilis) and buffalograss (Buchloe dactyloides). This effort largely failed because of inadequate moisture conditions. A second attempt at reseeding occurred in the spring of 1992 following a herbicide treatment with 2,4-D amine to control broadleaf weeds. The seeding in 1992 included blue grama, buffalograss, sideoats grama (Bouteloua curtipendula), western wheatgrass (Agropyron smithii), switchgrass (Panicum virgatum), and galleta (Hilaria jamesii).

During my visit in May 1992 it appeared that the herbicide application was largely ineffective possibly due to low application rates and a recommendation was made to re-spray prior to seedling emergence from the most recent seeding. The site is dominated by kochia (Kochia scoparia), Russian thistle (Salsola iberica), and various mustard species.

This site is in a very early stage of secondary succession. If the herbicide treatment is effective in reducing the presence of annual forbs and if the seeded species become established, the site could become dominated by warm season grasses within 2 years. If this indeed is the scenario, then the site should be managed as follows. If annual forbs compose more than 25% of the relative canopy cover in the spring of 1993 then the site should be sprayed again with 2,4-D amine. A determination of whether reseeding is needed can only be made after the site is evaluated for perennial establishment from the 1992 seeding.

If the relative cover of annual forbs is less than 25%, then no spraying should be done. Over time the perennial component should increase and the annual component decrease. Spraying should only be considered a management alternative if the annual component continues to increase in future years.

The are a number of additional grass and forb species that could be established on this site to create a species composition that would more closely approximately the conditions of the site when the fort was established. The list of species in the Management Plan and Environmental Assessment for Bent's Old Fort

that are recommended for reestablishment can be used as a basis for selecting future species for restoration work on this site. Additional grass species that should be considered are sand dropseed (Sporobolus cryptandrus) and alkali sacaton (Sporobolus airoides). Potential forb species include blanket flower (Gaillardia aristata), blazing star (Liatris punctata), scarlet globemallow (Sphaeralceae coccinea), longleaf phlox (Phlox longifolia), beard tongue (Penstemon angustifolia), and yellow violet (Viola nuttallii). There are two primary limitations to establishing many of these species. The first is the fact that seed is not available for many of these species on a commercial basis. The second limitation is that these species do not exist in large enough numbers within the boundaries of the historic site to collect seed for propagation or direct planting. Therefore the approach for establishing species of limited availability is to contract with a seed collector to collect seed of the desired species within a 50 mile radius of the Fort on sites with similar soil and topographic characteristics. This seed could be increased at a SCS plant materials center or planted directly on site. If enough plant material can be obtained for seeding, then those species should be broadcast seeded over the site and covered with soil by light harrowing. This should be a procedure that moves that soil around in bare areas but does not disturb the established plants. Interseeders are available for drill seeding in established stands of vegetation. These implements normally scalp a furrow and plant seed in this opening. I would recommend against

this approach because it creates an artificial looking site that may last for 5 to 10 years. For those species that have only limited seed availability, the best approach would be to use this seed to produce transplants. These transplants could then be planted in a random, uniform, or clumped distribution. Openings should be created in the canopy, if needed, for transplant success. All plantings, seed and transplants should be done in early spring for greatest success.

Unit 2--Alfalfa Field

The alfalfa field in Unit 2 needs to be converted to native prairie in the near future. This action will require the removal of the alfalfa stand and then establishment of perennial grasses and forbs. This can be accomplished with more than one approach. The first option is to cut the alfalfa and remove the hay in late summer or early fall. Early the following spring the field could be plowed and planted to a perennial mixture of prairie species. A variation of this option would be to chisel plow the field in the fall after cutting the alfalfa. This would leave a rough surface and some stubble in place to control erosion over the winter and spring. Seeding would then be done in March (as soon as soils are dry enough to mechanically manipulate) following disking of the site to create a more favorable seedbed. I prefer the second option because the alfalfa kill should be greater with treatment in the fall.

The site should be broadcast seeded with the species listed

below. Following broadcasting, the site should be lightly harrowed to cover the seed. No fertilizer will be needed and the site should be mulched following seeding with a seed free mulch. If a seed free straw can be obtained, this mulch would be the best. Straw should be applied at a rate of 2 tons/acre and crimped into place to wind removal. If straw is not available, the site should be hydromulched with wood fiber at a rate of 1.5 tons/acre.
The following species are recommended for restoring the alfalfa field.

Common Name	Scientific Name	Seeding Rate[1] lbs PLS/Acre
Western wheatgrass, Arriba	Agropyron smithii	6
Blue grama, Lovington	Bouteloua gracilis	2
Sideoats grama, Vaughn	Bouteloua curtipendula	5
Buffalograss, Texoka	Buchloe dactyloides	5
Switchgrass, Grenville	Panicum virgatum	4
Sand dropseed, no cultivar	Sporobolus cryptandrus	1

[1]Broadcast seeding rate

The species listed above include specific cultivars that I would recommend if the plant material was purchased from a commercial supplier. The issue of genetic integrity must be addressed at Bent's Old Fort so that specific policy can be established for the selection of plant materials for future restoration work. I cannot make this decision for your particular situation, but only offer my opinion. For those Parks that have intact ecosystems of native species it makes ecological sense to try and maintain the genetic integrity of native species that are present. However, for those sites that have been heavily impacted

by overgrazing and cultivation, where the exotic component is as great, if not greater, than the native component, it appears from my perspective that the only realistic approach is restore native species without concern about maintaining genetic integrity. Therefore, my recommendation is to use commercial plant materials for most species and to select cultivars that would be adapted to the specific soil and climatic conditions of the area. For those species that are not commonly grown by seed suppliers, the recommendation is to have native collectors collect seed within a 100 to 150 mile radius of the Fort to supply the necessary plant materials. If the species selected for collection have good potential to produce seed and if propagation techniques are known, these species could be increased at a SCS plant materials center in order to provide larger quantities of seed over a longer time period.

One final item that needs to be addressed for all restoration work that is done in the future is the use of irrigation. Irrigation reduces the risk of restoration failure and therefore is a cultural practice that should be considered at Bent's Old Fort. To be effective, however, an irrigation system should be properly designed to achieve uniform coverage of the seeded area. A properly designed system will be relatively expensive and may be difficult to justify. If seeding is done as early in March as possible, I believe that success will be achieved unless drought conditions are prevalent. Under those circumstances that do not yield successful establishment, additional seeding attempts will be

needed. It is imperative that everyone involved with restoration work at Bent's Old Fort recognize the fact that some risk of failure does exist because of climatic uncertainties in this area.

Restoration of Old Road

The gravel road west of the Fort will be removed sometime in the future and will need to be restored. Before any restoration work begins on the road, I would recommend that soil samples be taken from 5 locations along the road. At each location, the soil should be sampled to a depth of 18 inches. Soil can be removed, with a shovel, to a depth of 18 inches and placed in a clean bucket. The soil can then be mixed in the bucket and a sample taken to represent that location. This process can be repeated for each location until 5 separate samples are obtained. These samples should be analyzed for pH, cation exchange capacity, electrical conductivity, total nitrogen, NO_3-N, plant available phosphorus and potassium, and texture. The results from these analyses will provide guidelines for any soil amendments that may be needed.

The gravel on the surface of the road should be removed as a first step in the restoration process. If needed, the roadbed should then be graded to return the area occupied by the road to an elevation consistent with the landscape adjacent to the roadbed. The site should then be ripped to a depth of 24 inches with ripper blades on the back of a road grader or a heavy duty chisel plow may be used to reduce soil compaction. If any soil amendments are

needed, they should be applied at this time and the area can be ripped a second time. If a source of topsoil is available, I would recommend that a thin layer of topsoil (2 to 4 inches) be placed over the ripped road base. The area can then be seeded to the same mixture proposed for the alfalfa field, using the same restoration procedures summarized above.

Dump Site

The dump site is in need of restoration work to return the site to an approximation of the original grade and establish a native grassland community. Waste materials that are present on the site should either be removed from the historical site or buried in place. The area should then be regraded to a condition that approximates the original contour of the area. The regraded soil material should then be sampled in 5 locations following the procedures recommended for the road. The results of these analyses will be used to develop specific recommendations for any soil amendments that may be needed. If topsoil is available, it should be spread over the regraded material to a depth of 2 to 4 inches. If topsoil is not available, then the regraded material should be reseeded directly. Restoration procedures should follow those outlined above, using the same species and seeding and mulching practices.

Saltgrass/Alkali Sacaton Unit

This site is located in the meadow areas on the south and east sides of the Fort. The dominant species should be inland saltgrass (Distichlis spicata) and alkali sacaton (Sporobolus airoides). However, heavy grazing over the years has removed many of the native species and exotics are abundant in this area. The goal for this area should be to remove annual and perennial exotics and increase the presence of natives. This goal may be achieved with one of several management approaches. The first alternative would be to use fire as a tool to shift species composition. Burning may be the oldest known practice used by humans to manipulate vegetation on prairie sites and could be an effective method at Bent's Old Fort. Controlled burning can achieve the following purposes: release plant nutrients in the soil and litter for plant use, reduce litter accumulation, control undesirable species, and stimulate the growth of desirable species. Prescribed burns must be carefully planned and executed so that the effects are beneficial. Because of the necessary planning and preparation that goes into prescribed burning it will not be possible to cover the topic in detail in this report.

The primary goal of burning would be to increase the abundance of native warm season species. Burning can be used to accomplish this goal by burning at the right time of year and under the correct climatic conditions. Burning early in the spring, after cool season species have begun growth but while the warm season species are still dormant will favor warm season species over cool

season species. Perennials that have broken spring dormancy and made considerable new growth are more damaged by intense fire than plants still dormant. It is also known that burning during dry years is apt to give more negative results than burning in years of average or above average precipitation.

If burning is selected as the management alternative, then frequency becomes an important issue. The use of prescribed fire would be most effective when repeated over time. The same site should be burned once every 5 to 7 years to continue to shift species composition and reduce the accumulation of litter.

A second management option to control exotics and increase native perennials is the use of grazing animals such as cattle. It is well demonstrated that different species of grazing animals have different forage preferences and the right combination of grazing animal species, season and system of grazing, and stocking rate results in heavy grazing of undesirable species and a competitive advantage for the favored plants.

This site could be effectively grazed by cattle in the spring or fall, over time, to reduce the presence of cool season species and increase the presence of warm season grasses. The grazing system that may work best would be a high intensity-short duration grazing method. With this approach the distribution of animals is good and the uniformity of plant use is greatest. However, to be effective the animals need to be fenced to restrict their movement. Temporary, electric fencing would be the only realistic way to proceed for this site. The length of grazing would be restricted

to 7 to 14 days in any fenced area, for example, and stocking rates should be determined based on forage availability. A local SCS office could be contacted to help develop a specific grazing plan if this approach was desirable.

With this approach, grazing animals would only be present on the site for a relatively short period of time, and if done in the spring, at a time when visitor numbers are relatively low.

A third option would be mowing. The combination of mowing and raking to remove the mowed material and litter may serve a similar function as grazing if done in the spring. Mowing should be done yearly until a substantial change is species composition is achieved. Once this occurs, then a mowing schedule of once every 3 years would be adequate to maintain the desired species. This alternative would be the least expensive and easiest to implement.

One final option would be deep plowing to remove all vegetation and reestablish a new community. This option is the most drastic and would be the most expensive, but would result in the most complete conversion to native prairie. It would entail plowing the entire unit in the spring. Plowing to a depth of 12 to 18 inches will bury the existing seed bank and the above portion of the existing plants. Roots will be exposed to desiccation to increase mortality. During the growing season the site should be chisel plowed or disked to remove any invading vegetation. The site should be left in a rough condition to prevent blowing during the fall and winter. The following spring the site should be seeded to an acceptable mixture of native perennials adapted to

this particular site. Such species as inland saltgrass, sand dropseed, western wheatgrass, squirrel-tail bottlebrush (Sitanion hystrix), and blue grama would be well suited to this site. Seeding and mulching practices would follow those proposed for the alfalfa field.

Cottonwood Site

The cottonwood site along the north side of the Arkansas River has been invaded by exotics and currently has poor regeneration of cottonwood (Populus sargentii) and willow (Salix interior). There are 3 possible approaches to managing this site to decrease the occurrence of exotics and increase the abundance of native species. The first option is to burn in the spring before the warm season grasses have broken dormancy. Burning in this community has its risks because of the potential impact on cottonwood trees. The site would have to be cleared of all ladder fuels before a burn was attempted. Following the burn I would recommend planting cuttings of both cottonwood and willow. There are many tricks of the trade in getting cuttings to root and I would, therefore, suggest that someone locally be contacted that has the knowledge necessary to propagate both cottonwood and willow and have them take cuttings from the site and develop rooted material for planting. Since burning and planting should be done in conjunction, timing would be critical in order to have the cuttings properly hardened before they are planted.

The second option would involve the use of cattle in a similar

fashion as described for the salt grass/alkali sacaton unit. High intensity-short duration grazing in the spring would be the best time for this site. Grazing could be used as a management tool to alter species composition and reduce litter accumulation for 3 to 4 years. After this time, cuttings of cottonwood and willow could be planted and allowed to grow for approximately 5 years before any additional grazing was allowed. At this time, the vegetation in the area would need to be evaluated to determine what additional manipulations are needed.

The third option would be to mow and rake. Mowing and raking could be used as a management approach in the spring for 4 years. Cottonwood and willow could be planted during any spring after mowing was initiated as long as mowing could be done without disturbing the transplants. After this 4 year period, mowing could continue on a 3 year rotational basis. The primary draw back of mowing, when compared to burning or grazing, is that the site will become depleted of organic matter and nutrients over time because the mowed material and litter are being removed. Therefore, proper judgement needs to be used in deciding whether raking should be done in conjunction with mowing in any given year. If litter build up is not extensive, then raking should be withheld.

Wetland Site

The wetland site is in good condition with respect to species composition. This area does not need to be manipulated either chemically, mechanically, or biologically. However, burning the

site would prove to be of benefit through the reduction of litter, release of nutrients, and through the creation of openings in the canopy to facilitate the establishment of new seedlings. The end result may be an increase in species diversity. At this time, my knowledge of the site is too limited to know if the area dries sufficiently during the summer months to carry a fire. If it does dry sufficiently, then the use of prescribed fire may be a management consideration.

I would suggest that a monitoring program be established in the wetlands to document vegetation changes that occur over time in order to justify specific management practices that may be needed in the future. Specific recommendations for establishing a monitoring program can be found in a later section of this report.

Old Fields and Pasture Unit

Most of the 400 acres south of the Arkansas River have been cultivated in the past and are in various stages of recovery. One section supports an active prairie dog colony and the vegetation in this area is dominated by annual forbs and grasses that are almost entirely exotic. Because each area is in a different seral stage of plant community development, restoration practices need to be site specific.

Cultivated Area with Prairie Dog Colony

Creating a new plant community in the prairie dog colony will not be easy because of the continual impact of prairie dogs on

establishing vegetation. The easiest way to restore prairie in this site would be to temporarily remove the prairie dogs during the time the plant community is establishing. Assuming that this is not the preferred alternative of the Park Service, then the only approach that I am aware of is to establish plant species that will either tolerate the presence of prairie dogs or will not be readily eaten. The approach that I would recommend is to chisel plow the entire site in late fall and seed the area in early spring to western wheatgrass, blue grama, and buffalograss. In addition, seed should be collected from the stand of sand sagebrush (Artemisia filifolia) that is adjacent to this site. This seed could be given to an SCS plant materials center to produce transplants that should then be planted at the same time as seeding. The transplants should be uniformly planted throughout the site and spaced 3 feet apart. Natural mortality will thin the stand and create a more natural appearance over time. The transplants should be caged to prevent animal use for at least three years.

The previously cultivated area surrounding the prairie dog colony also needs to be restored. This area is in an early stage of succession and is dominated by annual weeds. This site should be deep plowed in the spring to bury the seed bank and expose roots. During the growing season after plowing there will be some growth of annuals. The site should be disked one time during the growing season to prevent these annuals from setting seed. The surface of the seedbed should be left rough to reduce blowing. The

site should then be seeded early the following spring with the seed mixture listed below. Revegetation methods should follow those described for the alfalfa field.

Common Name	Scientific Name	Seeding Rate[1] lbs PLS/Acre
Western wheatgrass, Arriba	Agropyron smithii	5
Blue grama, Lovington	Bouteloua gracilis	2
Sideoats grama, Vaughn	Bouteloua curtipendula	4
Buffalograss, Texoka	Buchloe dactyloides	5
Switchgrass, Grenville	Panicum virgatum	4
Sand dropseed, no cultivar	Sporobolus cryptandrus	1
Needle & thread, no cultivar	Stipa comata	2

[1]Broadcast seeding rate

Stipa Site

This area is in good condition and little manipulation would be needed to alter species composition. There are some exotics in this area, but the dominant species are native perennials. This site will need to be properly managed to maintain the current species and encourage the establishment of additional natives. I would suggest grazing the site with cattle in the spring on a 3 year rotational basis. A high intensity-short duration system would again be recommended for this area. This will keep litter accumulation in control and may encourage greater species diversity. Prescribed burning could be used as an alternative to grazing, with a burn planned every 5 to 7 years.

Next to this area is a berm that may be associated with a road that went through this site. This berm should be graded down to what was the original contour. This earth moving activity will result in a disturbance to the surrounding plant communities and

the entire disturbed area should the be seeded to the seed mixture proposed for the area surrounding the prairie dog colony, following the same procedures described for the alfalfa field.

Sand Sagebrush Site

This site is dominated by sand sagebrush and blue grama and has a very limited number of exotics present. My recommendation is to maintain the sagebrush community in its present state with a minimum level of management. There is not an abundance of litter accumulating on this site and litter build up should be monitored over time to determine if it becomes a problem. Burning or mowing are not appropriate management approaches for this site because of the shrub component. Grazing could be used to manage the vegetation by grazing in spring or fall on a 5 year rotational basis. The same grazing system as recommended previously would be best for this small area.

Area North of Cultivated Site

This area was also previously cultivated but is more advanced successionally than the area to its immediate south. This area has a good stand of needle and thread but is also heavily invaded with a number of exotic species including bindweed (Convolvulus arvensis). This site should be sprayed with 2,4-D amine in the spring of the year when the annuals are 3-4 inches tall. The next spring should include another spraying unless the weed component is less than 25% of the canopy cover. The site should be drill seeded

in early spring of this second year with the species listed below. If spraying is called for the second year, it should be done prior to emergence of the seeded species.

Common Name	Scientific Name	Seeding Rate[1] lbs PLS/Acre
Western wheatgrass, Arriba	Agropyron smithii	4
Blue grama, Lovington	Bouteloua gracilis	1
Sideoats grama, Vaughn	Bouteloua curtipendula	3
Buffalograss, Texoka	Buchloe dactyloides	2
Switchgrass, Grenville	Panicum virgatum	2
Sand dropseed, no cultivar	Sporobolus cryptandrus	1

[1]Drill seeding rate

Saltcedar Control

Saltcedar (Tamarix ramosissima) invasion is heavy along the Arkansas River and especially in the south unit of the site. Every effort should be made to eradicate this species from the site using mechanical and chemical approaches. The best approach to killing saltcedar is by excavating the growing point which is belowground. If this is not possible then cutting the stump and treating with Garlon may be the next most effective treatment. Because of the extent of invasion and the size of existing plants, the control of saltcedar will require an intensive effort for a number of years.

LONG-TERM MONITORING PROGRAM

The success of any restoration activity can only be confirmed with vegetation monitoring to determine species responses that occur following the implementation of a management strategy. Expending time and money to restore a site without monitoring to

judge success may be an expensive investment that will yield poor returns.

A knowledge of the direction of vegetation change is needed to determine whether the vegetation condition is improving or deteriorating under the existing biotic and abiotic influences. An objective determination of a change requires monitoring over a long period of time. A well-conceived sampling design is a prerequisite to any monitoring program. The choice of a sampling design is dictated, in part, by the objectives of the monitoring program, the vegetation type, the vegetation characteristics being measured, and the availability of financial and technical resources. Designs most frequently used are random sampling and permanent plots. Sampling locations within a vegetation unit may be selected at random at each measurement time, or repeated measurements may be obtained on the points selected at random the first time. If the later approach is selected, then the position of the selected points must be permanently marked on the ground by driving steel rods to facilitate exact relocation of the plots or lines.

My recommendation for establishing a monitoring program is as follows. In each vegetation unit that monitoring is needed, a minimum of six, 100 foot transects should be randomly located (if the unit is greater than 60 acres in size then one transect should be added for each additional 10 acres). The beginning, middle, and end of the transect should be marked with a steel rod. A small portion of the rod should be exposed to facilitate relocation. A detailed description of the location of the rods must be recorded

for future reference. Once the transect is in place, a metal rod, with a sharp point, is lowered at one foot intervals to record 100 hits per transect. The rod must be lowered in a vertical line, perpendicular to the plane of the ground surface. Whatever is first encountered by the point is recorded as a single hit. If the hit is a plant, then the specific species is recorded. If the hit is bareground, litter, or rock, then one of these is recorded. The number of hits are then tallied together. Each hit represent 1% cover. If blue grama is encountered 20 times along the transect, then blue gram is showing 20% canopy cover. If along the same transect, there were 25 hits of bareground and 15 hits of litter, then this would mean that there was 25% bareground and 15% of the ground surface was covered with litter.

This procedure is called a line transect and point intercept method and is commonly used in grassland communities. This method provides a fairly unbiased rapid approach to sampling vegetation that can be repeated over time without destructively sampling the vegetation. The data along each transect can be recorded in 20 minutes if the one conducting the sampling is familiar with the species present. With this approach it will be possible to detect changes in the cover of individual species in 1% increments. This level of precision should be more than adequate for the needs of this site.

SEED COLLECTION

There may only be a few species within the boundaries of the historical site that are abundant enough to warrant a seed collection effort. Blue grama, needle and thread, sand sage, and scarlet globemallow may be present in enough quantity to provide adequate seed for collection. There may be other native species abundant enough to consider in a seed collection program that were not sufficiently advance phenologically during my visit to identify. It would be helpful to have someone like Wendell Hassell visit the site and make an assessment of the potential for seed collection. With respect to references, there is one excellent book available on seed collection of native species by James and Cheryl Young, entitled "Collecting, Processing and Germinating Seeds of Wildland Plants. The book is published by Timber Press, Portland Oregon, copyrighted in 1986.

THREATENED AND ENDANGERED SPECIES SURVEY

If a threatened and endangered plant species survey is needed I recommend that you contact the U.S. Fish and Wildlife Service to provide guidance for the survey. They will give you a list of plant species that potentially could occur in your area and also recommend a specialist that would be familiar with the species of concern. They may also have a specific protocol to follow for conduction the survey.

CONCLUSIONS

As I conclude this set of recommendations for Bent's Old Fort, it is important to emphasize the fact that restoration will be a long-term endeavor for this site. The area has a long history of agricultural activity and the grasslands that do exist have been mismanaged for many years. Most of the native species that were present in the early 1800s are no longer present and many early seral species and exotics are occupying the niches once filled by these native perennial grasses and forbs. I recommend that the various units within the monument boundaries be prioritized and that restoration take place in a systematic fashion. The areas north of the Arkansas River and specifically those areas immediately surrounding the Fort should receive immediate attention. After restoration activities have begun on all of the north units, then your attention can be turned to those areas south of the river. This is true except for control of saltcedar. Control of this species is an immediate concern and activities in this area should be ongoing until the problem is under control. In the south units, the prairie dog colony and the land area surrounding the colony should be the highest priority.

KNIFE RIVER INDIAN VILLAGES

NATIONAL HISTORIC SITE

SECTION B

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INTRODUCTION

The following recommendations are based on a site visit to the Knife River Indian Villages National Historic Site that I made on June 8 and 9 1992. The site has been intensively impacted by cultivation and subsequent seeding with exotic perennial grasses. Other cultivated areas have been allowed to restore naturally and these areas are also being invaded by exotic perennials. A vegetation baseline study was conducted of the site in 1984 by Gary Clambey (Clambey 1985). The results of this survey indicated that there are 5 vegetation types within the site boundary and include: 1) prairie, 2) riparian forest, 3) sandbar and riverbank vegetation, 4) former cropland that may have been revegetated, and 5) previously cultivated land that has not been revegetated. These 5 vegetation types have been mapped for KNRI.

During my visit, a number of short, intermediate, and long-term goals were identified for restoration activities. This report will address each of these goals and provide specific recommendations that would be culturally, ecologically, and economically acceptable.

It is important to keep in mind that the issues being addressed, by their very nature, will require long-term solutions. Those goals that are labeled short-term do not necessarily represent issues that can be solved in a short period of time but are goals that represent higher priorities or problems that need immediate attention. The evaluation of any restoration activity

should be judged in light of existing abiotic and biotic conditions that exist at the time that management strategies are implemented. The success of any strategy will be controlled by weather conditions, soil factors, and animal interactions.

RECOMMENDATIONS FOR RESTORATION ACTIVITIES

Short-Term Goals

Big Hidatsa Site

The vegetation at the Big Hidatsa Village site has been mechanically mowed for a number of years to keep the vegetation short and allow park visitors the opportunity to visualize the physical features of the area. It appears that this mowing has created an environment favoring the continued dominance by kochia (Kochia scoparin) in the areas surrounding the depressions. The depressions represent sites that have more favorable soil moisture relationships and are dominated by perennial grass species that appear to be native. The goal for this area is to remove the kochia and create a plant community type that would characterize the site at the time that the Hidatsa Indians occupied this area. Although the early descriptions of the vegetation in these areas is not detailed, it is assumed that the site would have supported a mixed grass prairie with such grass species as green needlegrass, western wheatgrass, blue grama, sideoats grama, big and little bluestem, and junegrass being common.

One reason that kochia may be dominating this site is related to the available nitrogen levels that are present in the soil.

Without specific data on the chemical properties of these soils any interpretations that are drawn simply represent speculation at this point in time. However, research that I have been involved in (McLendon and Redente 1991 and 1992) since 1984 indicates that elevated levels of plant available nitrogen promotes the dominance of kochia and that succession from seral stages dominated by annuals to later seral stages dominated by perennials can be delayed by adding nitrogen and accelerated by reducing available nitrogen. With this as a basis for treating the kochia problem, it may be possible to convert the site to perennial grasses by immobilizing nitrogen. This could be accomplished over a 2 to 3 year period by adding sucrose at a rate of 1,600 kg/ha/yr. This amount of sucrose cannot be applied in one dose and should be divided into 5 equal applications separated by approximately 30 days, beginning early spring just prior to the initiation of new growth. The application of sucrose should be supplemented with seeding of native perennial grasses and forbs to provide a seed source. This seeding should consist of a diverse mix of grasses and forbs each year that the sucrose is applied. Cool season species should be hand broadcast over the site in the fall and warm season species in the spring (Tables 1 and 2). Mulching following seeding is not necessary because of existing live and dead vegetation on the site. Mowing should be continued during the first year that sucrose is applied. The next 2 years should not be mowed so that new grass and forb seedlings can establish and

produce seed. The success of the treatment should be evaluated each year and adjustments made as warranted.

Table 1. Cool season species to be seeded on the Big Hidatsa site in the fall.

Common Name	Scientific Name	Seeding Rate lbs PLS/Acre
Western wheatgrass, Mandan	Agropyron smithii	2
Green needlegrass, Lodorm	Stipa viridula	2
Junegrass	Koeleria cristata	1
Scarlet globemallow	Sphaeralcea coccinea	1

Table 2. Warm season species to be seeded on the Big Hidatsa site in the spring.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Blue grama	Bouteloua gracilis	1
Sideoats grama, Pierre	Bouteloua curtipendula	1
Big bluestem	Andropogon gerardi	2
Little bluestem	Andropogon scoparius	2

A second alternative to the application of sucrose would be to spray the kochia dominated areas with 2,4-D amine when the plants reach a height of 4 to 5 inches in the spring. The site should be observed throughout the growing season and sprayed again if dominance by broadleaf annuals continues. The site should then be broadcast seeded to perennial grasses and forbs the following spring after litter on the site is removed by natural processes, such as decomposition. The seeding rate should be at about 25 lbs/ac as shown in Table 3. The success of this approach must also be evaluated to determine if modifications in the approach are needed.

Table 3. Native grasses and forbs for seeding following herbicide treatment of Hidatsa site.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Mandan	Agropyron smithii	4
Green needlegrass, Lodorm	Stipa viridula	5
Junegrass	Koeleria cristata	2
Blue grama	Bouteloua gracilis	1.5
Sideoats grama, Pierre	Bouteloua curtipendula	1.5
Big bluestem	Andropogon gerardi	3
Little bluestem	Andropogon scoparius	5
Scarlet globemallow	Sphaeralcea coccinea	3

Cultivated Field Seeded To Oats

A once cultivated field of approximately 50 acres that was invaded by a mixture of exotic and native vegetation was plowed in 1991 and seeded to an annual crop of oats. The seeding, as observed in June, was very successful except in one area where the soil texture was sand. The goal for this site is to establish a native prairie before the area is reinvaded by undesirable species. This goal can be achieved by one of two approaches. The first is to drill seed into an oat stubble, in the spring of 1993, a mixture of grasses and forbs (Table 5). The second approach would be to obtain native hay and disc this hay into the oat stubble at an application rate of 1 to 2 tons/acre. If the native hay is dominated by warm season species then the hay should be applied in the spring, if dominated by cool season species then it should be applied in the fall. If the hay is held over winter, it should be kept dry to maintain as much seed viability as possible. Either approach would be effective and the decision could be based solely on economic constraints. Success should be monitored and it may be

necessary to mow the site if annuals become a problem. The best time to mow annual weeds is just at the time of flowering to prevent seed formation. This usually occurs early enough in the growing season that the mowing will not prevent the perennials from completing their phenological development.

If this approach is successful it may provide a strategy for converting other sites to native prairie that are currently dominated by exotics. Therefore close observations should occur to document species composition changes that will occur with time. In addition, it should be noted that once a prairie stand is established it must be managed to reduce litter accumulation and to stimulated tiller development of the grass species. This can be accomplished through mowing and raking the vegetation, by burning, or by grazing. Whatever method or combination of methods is selected, the herbage removal should occur on a 4 to 6 year rotation depending upon climatic conditions (wet versus dry) and grazing by native herbivores.

Old Alfalfa Fields

There are two fields in the park that were cultivated for alfalfa and have since reverted to grassland sites. The two sites are dominated by exotic grasses (smooth brome and Kentucky bluegrass) and should be managed to convert to native prairie. If the strategy used for the oat field is successful in establishing a native grassland, this provides an approach for treating these two fields. Assuming this is the case, the area

should be deep plowed to bury the existing vegetation and seed bank. The plowed site should then be disked and drill seeded to oats or other acceptable cover crop. The oats should be cut to produce a stubble and to prevent seed production. Seeding (Table 5) or disking of native hay would then follow as prescribed above.

If this approach is determined to be unacceptable, then the site should be managed as a grassland, accepting the fact that species composition will consist or mainly exotics and some natives. It may be possible to increase the diversity of native species over time by seeding native grasses and forbs into bare areas that occur naturally or by creating openings in the canopy (mechanically or chemically) and seeding natives. The establishment of patches of native species throughout these fields will provide a valuable source of seed for natural recolonization. This colonization will be a slow process and may never result in complete replacement of exotics.

Regardless of what approach is taken with these sites, litter accumulation will need to be a managed on a regular basis. This can be accomplished mechanically, biologically, or with fire as noted above, and should be done every 4 to 6 years.

Kreiger Site

The vegetation on the Kreiger site is dominated by native perennial grasses and forbs with only a limited exotic component. It is critical that this site be managed properly to preserve the native species and reduce the number of exotics over time.

The best management approach for the Kreiger site is to use prescribed fire on a rotational basis every 5 years. The entire area should be burned every 5 years, depending upon litter accumulation. Wet years will accumulate more litter than dry years, so the exact timing of a burn may vary between 4 and 6 years. If it is not practical or feasible to burn the entire Kreiger Site at one time or with one burn, then smaller sections could be burned in successive years until the entire area was treated. The sequence would then start over so that each section was treated on a rotational basis of approximately 5 years.

Restoration of the Oberlander Road

The Oberlander Road, located between the Sakakawea and Lower Hidatsa sites, will be removed and the area restored to native prairie. The road area should be graded to the approximate original contour that existed before the road was constructed. The entire site should then be ripped to a depth of 24 inches with the ripper blades on the back of a road grader (or similar piece of equipment) or a heavy duty chisel plow may be used to reduce compaction. The site may then need to be disked or harrowed to break up any large clods that are left from the ripping process. At this point the area should be broadcast seeded with the mixture of grasses and forbs that are provided in Table 4.

Table 4. Native grasses and forbs for seeding Oberlander Road.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Mandan	Agropyron smithii	5
Green needlegrass, Lodorm	Stipa viridula	5
Needle and thread	Stipa comata	2
Blue grama	Bouteloua gracilis	2
Sideoats grama, Pierre	Bouteloua curtipendula	2
Scarlet globemallow	Sphaeralcea coccinea	3
Purple prairie clover, Kaneb	Petalostemum purpureum	2

Intermediate-Term Goals

Use of Animals to Reduce Fuel Accumulation

A large amount of fuel is accumulating in the forested areas that will be a contributing cause of wildfires in the future. Because of the potential damage that these fires could cause to cultural resources in the area, it seems prudent to reduce fuel loading in these areas to reduce the fire hazard.

There are 2 potential management practices that could be tested to determine their effectiveness. The first approach would consist of mowing and raking to physically remove herbaceous plant material and litter. The difficultly associated with this method is that the areas of concern may have tree densities that are too high along with dense accumulations of fallen limbs to prevent adequate access with mowing equipment. The second alternative would be to use livestock as a tool to manipulate the vegetation.

Cattle, for example, could be used in the spring of the year to reduce herbaceous production and litter accumulation and over time alter plant species composition to encourage the establishment of native species. The grazing system that may work best would be

a high intensity-short duration grazing method. With this approach the distribution of animals is good and the uniformity of plant use is greatest. However, to be effective, the animals need to be fenced to restrict their movement. Temporary, electric fencing may be the least expensive approach to take in this situation. The length of the grazing period should be restricted to about 14 days in any fenced area and stocking rates should be determined after consultation with the Soil Conservation Service in your area. Stocking rate will be determined based on forage availability which can not be predicted at this point in time.

Grazing should be continued under this management system on an annual basis for 5 years and then a rotational scheme could be implemented where grazing would be used once every 3 years. The effectiveness of grazing or mowing should be monitored over time by measuring changes in plant species composition using ground cover as the measurement parameter. Cover can be determined for live vegetation, by species, and for litter and bare ground. A suggested approach for monitoring is included in the following paragraphs.

In each vegetation unit that monitoring is needed, a minimum of six, 100 foot transects should be randomly located (if the unit is greater than 60 acres in size then one transect should be added for each additional 10 acres). The beginning, middle, and end of the transect should be marked with a steel rod. A small portion of the rod should be exposed to facilitate relocation. A detailed description of the location of the rods must be recorded for future

reference. Once the transect is in place, a metal rod, with a sharp point, is lowered at one foot intervals to record 100 hits per transect. The rod must be lowered in a vertical line, perpendicular to the plane of the ground surface. Whatever is first encountered by the point is recorded as a single hit. If the hit is a plant, then the specific species is recorded. If the hit is bareground, litter, or rock, then one of these is recorded. The number of hits are then tallied together. Each hit represent 1% cover. If blue grama is encountered 20 times along the transect, then blue gram is showing 20% canopy cover. If along the same transect, there were 25 hits of bareground and 15 hits of litter, then this would mean that there was 25% bareground and 15% of the ground surface was covered with litter.

This procedure is called a line transect and point intercept method and is commonly used in grassland communities. This method provides a fairly unbiased rapid approach to sampling vegetation that can be repeated over time without destructively sampling the vegetation. The data along each transect can be recorded in 15 to 20 minutes if the one conducting the sampling is familiar with the species present. With this approach it will be possible to detect changes in the cover of individual species in 1% increments. This level of precision should be more than adequate for the needs of this site.

Long-Term Goals

Previously Cultivated Sites

There are several areas within the boundaries of the historic site that were previously cultivated and either seeded to grasses or allowed to revegetate naturally. Both areas are dominated by exotic perennial grasses such as smooth brome (Bromus inermis) and crested wheatgrass (Agropyron cristatum). Because of the dominance by exotic species, these areas should be managed to reduce the presence of exotics and increase the abundance of native grasses and forbs.

Because of the cultural resource at the Knife River Indian Villages National Historic Site there are specific restrictions associated with physically manipulating the soil. Because of this restriction the options available for converting exotic grasslands to native grasslands are quite limited. One approach is to spray the grassland sites with Roundup to kill all the existing vegetation. This could be done in small blocks of land to reduce the visual impact that this might have on visitors. Spraying of an area should occur 2 or 3 times during the growing season. The first spraying should be done in the spring, 2 to 3 weeks after initial growth has begun. Another spraying may be needed at the end of June or first of July and a final spraying at the beginning of August. If possible, the site should then be raked in September to remove as much of the dead plant material and litter as possible. In late fall (prior to snowfall) the site should be seeded to the mixture found in Table 5. Drilling the seed would be

the best option under these circumstances because of the limitation associated with disturbing the soil to create a favorable seedbed for broadcasting.

Table 5. Native grasses and forbs for seeding cultivated areas.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Mandan	Agropyron smithii	3
Green needlegrass, Lodorm	Stipa viridula	3
Needle and thread	Stipa comata	1
Blue grama	Bouteloua gracilis	0.5
Sideoats grama, Pierre	Bouteloua curtipendula	0.5
Big bluestem	Andropogon gerardi	2
Little bluestem	Andropogon scoparius	2
Scarlet globemallow	Sphaeralcea coccinea	1
Purple prairie clover, Kaneb	Petalostemum purpureum	1

The second option would be to burn the exotic grassland sites in the fall of the year with as hot a fire as possible and follow the burn with a seeding of the native species listed in Table 5. This approach will not eliminate exotic species but may reduce their abundance and provide openings for the native species to become established.

It is important that these grassland sites be properly managed after manipulation. This management should consist of burning or mowing and raking and should take place every 5 years. This management practice will help rejuvenate the grasses and reduce the accumulation of litter.

Indian Village Sites

The three Indian village sites (Big Hidatsa, Lower Hidatsa, and Sakakawea) are currently mowed every year to provide better viewing of these areas by visitors. It would be beneficial to establish a rotational mowing schedule to allow the perennial grasses and forbs on these sites to produce seed for new seedling establishment. Each site should be allowed to produce seed once every 3 years. With this schedule, 2 sites would be mowed each year and one site would be allowed to produce seed.

CONCLUSIONS

Restoration activities at this site will require a long-term commitment to be successful. The Kreiger site is the only prairie that has many native species still present. The cultivated areas are dominated by exotic grasses, the forested areas have understories dominated by exotic grasses and forbs, the Big Hidatsa site is in a very early stage of seral development with a near monoculture of kochia. Although I have not discussed the problem of noxious weeds, the area has been infested with leafy spurge (Euphorbia esula) and the existing spraying program will need to continue for several more years.

Each area within the historical site will need to be managed in a specific way to maximize the effectiveness of the proposed treatment. It will not be possible to eliminate all exotic species, but it should be possible to reestablish grassland sites that are dominated by natives. The long-term survival of these

species, however, will depend on the application of sound ecological and management practices. For example, fire is an integral component of grassland ecosystems and should be used as a management practice to promote healthy grasslands.

Finally, it should be noted that successful restoration is not only dependent on selecting the correct management practice and proper implementation of that practice, but also upon natural phenomenon, such as climate, that is beyond man's control. Flexibility is an important ingredient to any restoration program to adjust to changing environmental conditions that will occur over time.

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THEODORE ROOSEVELT NATIONAL PARK

SECTION C

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INTRODUCTION

A site visit was made to Theodore Roosevelt National Park on June 10 and 11, 1992 to assess the condition of existing prairie sites and provide recommendations for control of noxious weeds and restoration of grassland sites that are dominated by exotic species. The grasslands at Theodore Roosevelt National Park are a representation of heavy grazing that occurred in the late 1800s along with cultivation that took place in the uplands. Cultivation was common in this area until the drought of the 1930s. It is unknown as to the extent that cultivated areas were reseeded as opposed to allowing natural revegetation to take place. However, some seeding was done as is evidenced by the presence of smooth brome (Bromus inermis) and crested wheatgrass (Agropyron cristatum).

There are a number of species of large herbivores in the park (e.g. bison, elk, deer, wild horses and longhorn steers) that have significant influence on the prairie vegetation. Prairie sites are currently being managed to establish and maintain prairie ecosystems that existed prior to settlement.

It is important to note that the implementation of recommendations contained in this report will require a long-term commitment of resources. The condition of the prairie in Theodore Roosevelt National Park represents decades of abuse and mismanagement prior to establishment of the Park. Overcoming the effects of these management practices will be a long-term process.

In addition, the evaluation of any restoration activity should be judged in light of existing abiotic and biotic conditions that exist at the time that management strategies are implemented. The success of any strategy will be controlled by weather conditions, soil factors, and animal interactions.

RECOMMENDATIONS FOR RESTORATION ACTIVITIES

Leafy Spurge Control

Background

Leafy spurge (*Euphorbia esula*) is one of the most aggressive and troublesome plants in the western United States. Of the approximately 2.5 million acres infested with leafy spurge, more than half are in North Dakota and Montana. Leafy spurge occupies a broad ecological range of habitats, from xeric to subhumid, and from subtropical and subartic. It will tolerate flooding over periods of at least four to five months, provided the shoots can grow above the water surface. Although leafy spurge frequently becomes established in moist places, it also is well adapted to dry, upland sites and shallow, rocky soils. Leafy spurge grows in nearly all soil types, but it appears to favor coarse textured soils.

The aggressiveness of leafy spurge largely can be related to its phenomenal ability to spread by producing horizontal roots, to propagate by producing buds profusely, and thus, to establish long-lived dense infestations. Leafy spurge seedlings growing without competition develop roots that can penetrate to a 3-foot depth in

four months and attain a lateral spread of 40 inches. Leafy spurge's deep root system allows it to survive without top growth for five or more years. Stems originating from the roots of leafy spurge begin growth in April, making it one of the first plants to emerge in the spring. This early and rapid growth helps give this species its competitive advantage over most other plants.

Seed yield from leafy spurge patches has been calculated to range from 24 to 2,400 pounds per acre. When the capsules that contain seeds dry, they explode and distribute the seed fairly uniformly from 1 to 13 feet from the plant. The ability of the seed to float and germinate in water is an advantage for spurge establishment in areas that flood occasionally.

Leafy spurge seeds remain viable in the soil for as long as 8 years (Lacey et al. 1985). Large seed reserves in the soil, coupled with seed dormancy and a phenomenal ability to emerge from deep roots enables an established stand of leafy spurge to survive repeated control attempts.

There have also been some reports that leafy spurge may be allelopathic to other plants under laboratory conditions. Allelopathy also is suggested by the small number of forbs in leafy spurge patches, even when bare ground is visible between shoots.

Leafy spurge is a serious problem in Theodore Roosevelt National Park and its invasion has resulted in the disruption of native plant communities and is threatening the survival of several rare plant communities. In addition, leafy spurge has no forage value to the large herbivores in the Park and its presence is

therefore reducing the carrying capacity of the area.

Leafy spurge control began in the Park in 1975 and currently consists of limited herbicide applications and a biological control program in cooperation with the Animal and Plant Health Inspection Service, Agricultural Research Service, North Dakota Department of Agriculture, and North Dakota State University.

The success of chemical control has been limited because of limited resources, difficult access in the backcountry, and the designated wilderness. The biological control program is limited to a small scale at the present time and the ability to use this approach on a large scale may be ten years away. The Park has recently proposed to evaluate the use of micro-foil boom helicopter spraying with monies from the Prairie Restoration NRPP program. This approach to chemical spraying is highly specialized and using a boom capable of precise targeting of chemicals with virtually no chemical drift. It is believed that heavy chemical treatment of leafy spurge for a few years will reduce infestation levels to a point that small amounts of spot treatment would result in long-term reduction in herbicide use and eventual control of this pest. However, the use of helicopters is very site specific and not suitable for all situations. An Integrated Pest Management (IPM) approach is being proposed for the next 10 years to include such methods as chemical treatment, biological agents, mechanical methods such as mowing, physical methods such as solarization by placing plastic sheets over patches of spurge, and prescribed burning in conjunction with chemical treatment.

Strategies for Leafy Spurge Control

Because of the aggressiveness and persistence of leafy spurge, its control in Theodore Roosevelt National Park must be given a high priority. I am sure there are many natural resource issues in the Park that are important and require immediate attention. However, from my perspective, the leafy spurge issues may be the most important and certainly is the most urgent. Every year that passes without adequate control, the problem multiplies as more and more acres are infested.

Biological control holds promise and may be the most ecologically sound approach to control spurge. However, attempts to establish control agents in the U.S. have met with only limited success. For example, the spurge hawkmoth has been worked with in North America since 1963, but only a few locations in the U.S. have reported good establishment. The moth does not overwinter well and is also susceptible to a virus that causes severe mortality once colonies build to a certain density. As we experiment with biological control agents, leafy spurge continues to invade and dominate native plant communities. My recommendation is to use an IPM program to control spurge. However, I believe that chemical applications and burning should initially be emphasized in combination with reseeding of native species. Spraying in September with Tordon and 2,4-D, burning in April and then repeating this process by spraying in June and burning in October have proven to be effective in controlling stands of leafy spurge.

This approach would be very labor intensive and should be limited to the largest stands of spurge in the Park.

The use of herbicides alone have also proven to be effective, but the application of chemicals must be repeated for several years and multiple applications in a single year appear to be highly effective. The use of Tordon and 2,4-D in mid to late June and again in September after fall regrowth for a minimum of 4 years may be the next best method of control spurge.

Some experimenting with new chemicals such as flouroxypyr and sulfomenturon should be done in the Park to determine their effectiveness and potential large scale use. Other management approaches such as mowing and solarization should also be tested on a small scale to determine their utility for a large scale control program.

To be consistent with these recommendations, I support the proposed helicopter spraying with micro-foil booms, where applicable. Those stands of spurge that would lend themselves to helicopter spraying (e.g. size and location) should be identified and treated twice annually for several years. Other stands should be treated by hand on a similar schedule and should include as many acres as economically feasible. Every attempt should be made to treat 70% of the infested acreage each year.

A critical component of the control program should consist of mapping of existing stands of leafy spurge with some quantification of acreage and stems per unit area. The development of a good baseline map will aid in developing a well orchestrated treatment

program. The use of state of the art remote sensing approaches should be explored as a method of creating this map. In addition, treated stands should be monitored over time to determine the effectiveness of the treatment being applied, whether it be spraying and burning, spraying alone, biocontrol agents, or the use of such practices as mowing and solarization. A couple simple measurements, such as size of infested area, along with an estimate of stem density would be adequate for long-term monitoring.

Finally, I strongly recommend that a workshop be sponsored by NPS to address the issue of leafy spurge control. There are a number of weed control experts (I do not include myself in this list) that could be brought together for a one day session to develop a consensus approach for controlling this pervasive species. A workshop would provide the opportunity for scientists and manageres working with the biological control of leafy spurge to share current information. For example, both seep and goats have been used to control the spread of leafy spurge. However, this biological control has not been effective in eradicating spurge, but has been effective in reducing density and controlling spread. Potential negative effects associated with the spread of diseases to native ungulates is an important issue that needs to be addressed in a workshop setting.

Road Realignments

I had the opportunity to visit 2 past road realignment projects (north entrance road and Buck Hill) and one proposed

realignment (Boicourt Slide Area). The following section includes a brief evaluation of the condition of the earlier revegetation attempts and recommendations for restoring the new road construction project for the Boicourt Slide Area.

The success of the revegetation done on the old alignment at Buck Hill is mixed. In places there is very good ground cover with a mixture of native and exotic grasses. In other areas ground cover is more limited with grasses and shrubs dominating but improper grading has resulted in water channelization and gullying. This area that is eroding should be treated to prevent the gullying from expanding. Rock could be used at the head of the gully to prevent any further head cutting. In addition the gully could be filled with soil and reseeded to species such as western wheatgrass (Agropyron smithii), blue grama (Bouteloua gracilis), needle and thread (Stipa comata), and little bluestem (Andropogon scoparius). This approach would be the least intensive and may prove to be effective if a good stand of grass can be established. If this attempt does not solve the gullying problem then it will be necessary to use heavy earth moving equipment to change the grade of the old road to eliminate this channelized flow of water. I would not recommend any additional seeding work along this alignment. The plant community that has established is a good beginning point and succession will bring it to a later seral stage over time.

The revegetation effort on the north entrance road in the North Unit has yielded an excellent stand of grass throughout the

entire alignment. However, the grasses that have established consist of a mixture of native and exotics. The area is dominated by western wheatgrass, smooth brome (Bromus inermis), crested wheatgrass (Agropyron cristatum), and Kentucky bluegrass (Poa pratense). Smooth brome, crested wheatgrass, and Kentucky bluegrass are the exotic species present and some effort should be put forth in the future to remove these species. This task, however, would require removing all species, by plowing for example, and reseeding the site to a mixture of native grasses and forbs. The only other option is to accept the presence of these exotic grasses and forego any further treatment of the area.

Boicourt Slide Repair

A large slump block, approximately 300 feet long, 70 feet high, and 150 feet wide, is located directly above the roadway near the Boicourt Overlook. Moisture at a depth of about 30 feet below the grade and the large surcharge load above the road are causing road problems such as cracking of the road surface. A major slide of the slump block could seriously damage the road, possibly removing an entire road section. In July 1986 a major slide occurred immediately adjacent to the present project area. In the summer of 1987 the road was reconstructed and adjacent disturbed areas reseeded. The area that was repaired is stable but fill failures are now occurring downhill.

The present proposal calls for removing approximately 10,000 cubic yards of slump material from above the road and moved to a

location below the road. The approximate 6 acres of total disturbed area would then be recountoured to reduce the slope and the site seeded. The area north of this project that was unsuccessfully seeded as part of the 1987 road reconstruction project will also be seeded at this time.

The proposed restoration plan calls for fertilizing the entire 6 acre site, seeding with native grasses, and mulching with straw. The following recommendations should be considered when developing final restoration plans for this site. First, it is important that fertilizer be held to a minimum. The addition of nitrogen (N) can stimulate the growth of annuals and rapid growing early successional species and hinder the development of native perennials. The use of phosphorus (P) is not believed to have the same stimulus effect but can be effective in stimulating root growth of the seeded species. Based on my understanding of soil fertility and soil/plant relationships, my recommendation is to add nitrogen at 25 lbs of total N/acre and phosphorus at 100 lbs of total P/acre. Both N and P should be incorporated into the upper 6 to 12 inches of the plant growth medium. Ideally, soil samples should be taken from the soil material that will be placed on the surface to serve as the plant growth medium. If it is known what this material will be before construction, then soil samples should be collected and analyzed to determine the actual need for N and P. A minimum of 5 soil samples should be taken for each acre to be disturbed. These soil samples should be analyzed for total N, NO_3-N, NH_4-N, and plant available P. The results from these analyses

should be used to determine fertilizer application rates.

Any soil compaction that occurs during construction should be reduced by ripping and the surface of the seedbed should be left rough. Seed should be broadcast in late fall or early spring using the seed mixture in Table 1. Fall seeding will favor cool season species, while spring seeding will favor warm season species. Following seeding, the area should be dragged with a light harrow to provided coverage of the seed.

Following seeding the area should be mulched with a seed free mulch. If a seed free straw can be obtained, this would be the best choice. Straw should be applied at 2 tons/acre and crimped into the soil to prevent loss due to blowing. If a seed free straw cannot be obtained then the site could be hydromulched following seeding with 1.5 tons/acre of wood fiber mulch. Both mulches are effective, but hydromulching is much more expensive than the use of straw. Therefore, if straw is available, it should be the mulch of choice.

Table 1. Seed mixture for Boicourt Slide repair.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Mandan	Agropyron smithii	4
Needle and thread	Stipa comata	3
Prairie junegrass	Koeleria cristata	2
Blue grama	Bouteloua gracilis	1
Buffalograss	Buchloe dactyloides	2
Prairie sandreed, Goshen	Calamovilfa longifolia	3
Little bluestem	Andropogon scoparius	4
Scarlet globemallow	Sphaeralcea coccinia	2
Fringed sage	Artemisia frigida	1
Winterfat	Eurotia lanata	1

Seed Collection

Restoration projects at Theodore Roosevelt National Park will require plant materials in fairly large quantities in order to be successful. There are basically 3 approaches that can be taken to obtain the required supply of seed. The first is to purchase seed commercially. The second is to collect seed within the Park and use this seed directly. The third option is to collect seed within the Park and use this seed in an increase program to multiply seed availability for future restoration projects.

Purchasing seed from a commercial supplier is the simplest approach and most likely the most inexpensive. Most of the dominant species that would be seeded in a restoration project are available commercially. Some of these species would have improved cultivars available that will provide some assurance that the seed being purchased will manifest certain genetic characteristics and be adapted to certain climatic and edaphic conditions. However, the majority of native species that would be needed will not be available as improved cultivars and care must therefore be exercised in purchasing this material. When purchasing seed of species without named cultivars it is essential to specify sources of seed that originate from environmental conditions similar to the conditions in which they will be planted. With this restriction, it may not always be possible to obtain the species that are needed in any one year.

The second approach provides plant materials that originate in the Park and have proven adaptability to the growing conditions

found within the Park. The two primary limitations associated with this option is the fact that seed is not produced every year by every species for which seed may be required and the amount of seed that can be collected within the Park will be somewhat limited. Seed production is subject to the vagaries of nature and natural phenomenon such as drought and insect infestations will affect seed production. Therefore, there will be years that some species will produce no seed or very limited amounts of viable seed. In those years that seed production is good, it still may not be possible to collect the quantity of seed that would be needed to seed a ten acre restoration project.

The third option may be the most expensive, but is one that provides the most assurance of quantity and adaptability. Relatively small quantities of seed can be collected in the Park and increased at a plant materials center. This increased seed will produce plants that are adapted to the growing conditions in the Park and quantities can be generated to meet specific restoration needs. This option does require lead time to produce specific quantities of seed. For example, if seed is needed to restore a ten acre disturbance in 1995, then seed would need to be collected in 1992. This 1992 seed could be planted in an increase field in the fall of 1992 or the spring of 1993 and seed would be available after the second growing season which would be 1995. Under this scenario a minimum of three years lead time would be required to produce seed for a specific restoration project.

Making a decision as to which approach is best for Theodore

Roosevelt National Park is difficult. Some parks have opted for the increase program in order to assure the availability of certain species in quantities needed for a specific project. Other parks have taken every step possible to maintain genetic purity of species and ecological integrity of communities and have chosen seed collection programs and increase programs to help accomplish this goal. In Theodore Roosevelt National Park the effect of past over grazing, cultivation, and invasion of exotic species is widespread. It may be very difficult to justify maintaining the genetic integrity of native species or the ecological integrity of a specific grassland community when the ecological integrity has already been violated by decades of mismanagement before the Park was ever established and genetic integrity may already be compromised with the use of plant materials that were not indigenous to the Park.

In addition, most of the dominant species that would be selected for restoration are available from commercial suppliers. This material can be purchased as improved cultivars or with restrictions with respect to geographic origin. It must be recognized that restoration efforts within this Park will never yield prairie sites that are composed of only native species or only native species that originated genetically from within the Park boundaries or even adjacent to the Park. To have this goal would be praise worthy, to achieve this goal would be unrealistic and impossible given the resources that would be available.

My recommendation for sources of plant materials for future

restoration projects is to purchase seed commercially for native plants with cultivars specifically adapted to the climatic, topographic, and edaphic conditions of the site in question. For those species that are not commercially available, I would recommend contracting with seed collectors to collect seed within the Park (if species are present in large enough quantities) or within a 100 mile radius of the Park. If the quantity of seed needed for a specific project cannot be obtained by this means, then those species should be collected in smaller quantities and increased at an SCS plant materials center. Advanced planning needs to occur to assure that seed is available when required.

Those species that are likely candidates for collection include needle and thread, green needlegrass, little bluestem, blue grama, prairie junegrass, prairie sandreed, buffalograss, scarlet globemallow, common yarrow (Achillea millefolium) and possibly purple coneflower (Ratibida columnifera) and silverleaf scurfpea (Psoralea argophylla).

The timing of seed collection is one of the most crucial and difficult steps in the process of collecting seed. Collection of immature seeds results in low seed viability or dormancy. The danger of delaying collection is that the fruits of many plants dehisce (fall from the seedhead) very rapidly, so seeds are lost if collection is delayed.

There is no substitute for experience in judging when to collect seeds of prairie species. To start a collection program for a species with which you have no previous experience is

difficult. Essentially you must investigate the phenology of the species to be collected. The principle stages of phenology that you would be interested in are flowering, seed formation, and seed maturity. Flowering is the first phenological stage of which you must be cognizant. Flowering is obvious for many species with colorful petals, sepals, and bracts; but careful attention is required to note anthesis (shedding of pollen) with many grasses. After flowering the sequence of phenology is as follows: 1) soft-dough stage--this stage is indicated by the excretion of dough from seeds when squeezed between the thumb and forefinger; seeds collected at this stage will normally not germinate; 2) hard-dough stage--the hard-dough stage can be judged by biting the seed, once the dough stage is completed; in other words, if you cannot squash the seed between the thumb and forefinger, try biting it; once the seed is fully mature, it is usually too hard to bite; seed collection should begin with the transition from soft to hard dough; 3) maturity--maturity and seed dehiscence may occur at the same time; to make sure some seeds will be obtained, repeated collections may be necessary; collections should extend from the later part of the soft dough stage until all seeds are lost.

During the collection process a random sample of seed (400 seeds) should be sent to a seed testing laboratory to conduct a tetrazolium test to determine the viability of the seed being collected. This test can be normally completed within 48 hours and will tell you if the seed you are collecting is viable and has the potential of germinating.

Seeds of grasses can often be collected by stripping. The process consists of allowing the grass stems to collect between the fingers and the seeds to be scraped from the terminal inflorescence as your hand moves forward. Another approach with grasses is to gather the inflorescence of the plant together and cut the stem just below the seed head.

Broadleaf herbaceous species (forbs) are more difficult to collect than grasses. The seeds of many forbs can be collected by holding a tray or box under the inflorescence while shaking or flailing the mature seeds into the receptacle. Fiber glass trays used in photographic darkrooms are excellent receptacles for this purpose or flat cake pans will work. For very small forbs, the simplest method of collection may be cutting the entire plant and bagging the material in paper sacks, leaving the bags open in a dry, well ventilated place until the seeds mature. Herbaceous species with capsules (such as scarlet globemallow) or other fruits that explode present a special problem for collection. The only way to collect seeds of this type is to carefully collect the fruits while they are immature and allow then to ripen to mesh bags. If the capsules are even touched at the right stage of maturity they will explode and the seed will be lost.

Shrub species can be collected by holding a tray or box under outstretched branches while flailing the bushes with a stick or paddle. Other species, such as sagebrush, can be stripped.

Seed Storage

Proper seed storage is a vital step in the seed collection process to guarantee viable seed. The two major concerns in storing seed are temperature and moisture. Two rules of thumb that relate to the influence of moisture and temperature on the rapidity of seed deterioration are: 1) each 1% reduction in seed moisture doubles the life of the seed and 2) each 10°F reduction in seed temperature doubles the life of the seed.

If seed moisture content is high enough (above 30%), nondormant seed will germinate. From about 18 to 30%, heating due to microbial activity will occur if oxygen is present, resulting in rapid death of the seed. From about 10% seed moisture for oily seeds and about 13 to 18% for starchy seeds, storage fungi grow actively and destroy the seed embryo. Therefore, seed should be dried as quickly as possible to below 13% seed moisture and should be stored below this moisture content at all times. However, drying to below 4 to 5% seed moisture will also result in more rapid deterioration than if seed is dried to a range of 6 to 10%.

To dry seeds, the relative humidity of the air must be below the equilibrium with seed moisture so there will be a moisture gradient from the seed to the air. Seeds can be dried in heated or unheated air but in most cases unheated air will not be effective in producing a safe moisture content. Therefore, heated air is most commonly used with an air temperature not to exceed 100°F. There should be good air flow around the seed and it is critical not to dry seed too rapidly because if the moisture gradient from

the seed surface is steeper than the moisture gradient from the interior of the seed to the seed surface, the surface will dry rapidly and cause cracking of the tissue or even shrink the outer cells and create a layer impervious to moisture.

The rule of thumb for temperature is applicable down to at least 32°F. If seed moisture is below 14%, no ice crystals form below the temperature at which seed freezes, so storage of dry seed at subfreezing temperatures should improve longevity. Unfortunately, most storage units that produce subfreezing temperatures also have high humidity and seeds will take on moisture over time unless the seed is placed in moisture-proof containers.

After seeds are dried to the desired moisture content, they must be kept at this level or the cost and benefit of drying the seed are lost. Maintaining the seed in a dry condition can be done in three different ways: 1) the storage unit is made moisture proof and has dehumidification equipment, 2) the seeds may be stored in moisture-proof containers, or 3) the seeds may be placed in gasketed containers with dry indicator silica gel (2 lbs of gel for every 10 pounds of seed). If drying and storage are done correctly, most of the seeds that would be used at Theodore Roosevelt would maintain good viability for several years at a minimum.

Previously Cultivated Areas

There are a number of areas in the North and South Units that

were cultivated in the past and most likely seeded to a perennial grass mixture. At the present time these sites are dominated by exotic grasses with a compliment of native grasses, forbs and half shrubs. The exotic species that appear to be most prevalent include smooth brome, cheatgrass (Bromus tectorum), Japanese brome (Bromus japanicus), Kentucky bluegrass, and crested wheatgrass.

There is no management practice that can be implemented that will remove the exotic species without also removing the natives. The use of fire, mowing, herbicides, or grazing cannot be used to selectively eliminate the undesirable species. This limitation affords only two alternatives to managing these prairie sites. The first option is to allow the exotics to coexist with the natives and to manage these sites as mixed grasslands of native and introduced species. The second option is to convert all of these cultivated grasslands to native prairie by complete removal of the existing vegetation and reseeding with natives. A complete conversion is possible but would require a long-term commitment of resources. The most realistic approach would be to treat 10 to 50 acre blocks of land sequentially over time until all areas are converted.

The best approach would be to spray the existing vegetation with Roundup in the spring and late summer, followed by deep plowing to a depth of 12 to 18 inches by the beginning of September. A deep plowing that turns the soil over will bury the existing seed bank and substantially reduce invasion by undesirable species. Early the following spring, as soon as the soil is dry

enough to work, the plowed area should be disked to prepare a seedbed. Once the seedbed is prepared the site should be broadcast seeded with the mixture in Table 2. Seed should be lightly covered with soil by dragging a harrow or similar implement over the seeded area. The site should then be mulched with a seed free straw, if available, or hydromulched.

Another approach would be to drill seed the plowed area in late fall with a cover crop such as Regreen at 10 lbs/acre. Regreen is a cross between wheatgrass and wheat and produces sterile seed. Regreen can be allowed to grow the next growing season and into this stubble the native mixture could be seeded the following fall. The stubble will increase snow accumulation and provide more moisture the following spring when germination and establishment of the perennial species occurs. This approach would delay establishment of perennial species by one year but may result in greater success.

Some criteria must be established to prioritize sites for restoration. The first step should be an inventory of areas to determine location, size, and description of species composition. Based on this information, those sites that contain significant amounts of noxious weeds, or serve some unique role within the park for wildlife habitat or visitor activity should be given highest priority. Specific criteria for making these decisions must come from park management.

Table 2. Seed mixture for previously cultivated areas.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Mandan	Agropyron smithii	3
Needle and thread	Stipa comata	3
Green needlegrass, Lodorm	Stipa viridula	2
Prairie junegrass	Koeleria cristata	2
Blue grama	Bouteloua gracilis	1
Buffalograss	Buchloe dactyloides	2
Prairie sandreed, Goshen	Calamovilfa longifolia	3
Little bluestem	Andropogon scoparius	4
Common yarrow	Achillea millefolium	1
Scarlet globemallow	Sphaeralcea coccinia	2
Purple coneflower	Ratibida columnifera	1
Fringed sage	Artemisia frigida	1
Winterfat	Eurotia lanata	1

Site Around Sewage Lagoon

The site around the sewage lagoon has been mowed annually for a number of years to provide forage for Park horses. Mowing every year over a long time period will have a negative effect on the existing vegetation because it reduces seed production among the perennial grasses and forbs. If this practice is continued long enough then the annual component of the community will be favored.

If mowing must be continued for the production of horse feed, then some modification of the current practice should be considered. One possibility is to select two other grassland sites and mow each site every third year. This mowing rotation will provide a rest period for each site to allow seed production to occur for the establishment of new seedlings.

The other concern for this site and other sites that may be mowed for horse feed, is the proliferation of exotics. The site around the sewage lagoon contains a number of exotic species. If this site is mowed at a time when exotics are setting seed (e.g.

cheatgrass and Japanese brome) this seed is then being spread to other areas in the Park. Care must be exercised in order to prevent this potential source of contamination from occurring.

Removal and Restoration of Corral Area

The fencing and wooded structures associated with the corral will be removed sometime in the near future. During the process of disassembling the corral and fences, all concrete should be removed and all large posts, that cannot be pulled, should be cut at least 12 inches below the soil surface. Once the structures are removed, the entire corral site should be chisel plowed to a 12 inch depth to reduce compaction. The entire site should then be broadcast seeded to the mixture shown in Table 1 in the fall (October) or spring (March-April). The seed should be covered lightly with soil following seeding with a harrow or similar implement. Mulching should then follow with a seed free straw or wood fiber hydromulch at the rates recommended earlier.

The road associated with the corral also needs to be restored and should be treated as follows. The first section of road to the corral site should be deep ripped with ripper bars on the back of a motor grader. Those portions of the road that have vegetation established (such as in the center median) should not be disturbed. The ripped portions should be broadcast seeded with the mixture in Table 1 (except for winterfat) in the fall (October) and lightly covered with soil. Mulching should not be needed on this restoration project.

The section of road after the corral should treated the same way in areas where vegetation is absent in the wheel tracks of the road. Those sections of the road that have vegetation existing across the entire road and where the vegetation is only matted should not be disturbed. This section of road should be allowed to restore naturally following the elimination of any further motorized vehicle activity.

Role of Fire in Maintaining Prairie Ecosystems in Roosevelt National Park

Regardless of origin, fires have always been common and widespread on prairies, especially during drought years. In semiarid areas, large prairie fires in the past usually occurred during drought years that followed one to three years of above average precipitation, because of the abundant and continuous fuel. There are no reliable historical records of fire frequencies in the Northern Great Plains grasslands because there are no trees to carry fire scars from which to estimate fire frequency. However, it is well known that fire frequency was high because explorers and settlers were concerned about the danger of prairie fires. It is possible to extrapolate fire frequency data for grasslands from forests having grassland understories, such as ponderosa pine (Pinus ponderosa). Fire frequency in pine forests vary from 2 to 25 years. Because prairie grassland is typically of level to rolling topography, a natural fire frequency of 5 to 10 years seems reasonable. In topography dissected with breaks and major

drainages, such as in the badlands, fire frequency may be 10 to 20 years.

Climate is the dominant factor controlling North American grasslands. On the eastern edge of the Great Plains the balance between forest and grassland is so delicate that a little higher water content of soil would shift the balance in favor of tree growth. Shrubs and trees have always existed as scattered individuals on grasslands and along drainageways. In the Northern Great Plains they are most abundant in the mesic edge of the northern mixed prairie. Shrubs and trees are also present on rocky breaks or heavily grazed areas where fires are least frequent. Droughts can control shrub abundance where grass is healthy, but shifts from grasslands to shrub and trees could occur on a 100 year cycle if vegetation was controlled solely by climate. Fire seems to have restricted shrub and tree growth in the past not so much as a single influence but in concert with other biotic and abiotic factors.

The amount of research on the effects of fire in the mixed grass prairie of the Northern Great Plains is limited. Some of the most informative papers have been published by Clarke et al. 1943, DeJong and MacDonald 1975, Hopkins et al. 1948, Launchbaugh 1964 and 1972, Coupland 1973, Rowe 1969, and Dix 1960. In general it is known that spring burning reduces grass yields 50% the first year, 15% the second year, with full recovery the third year. Fall burning decreases grass yields 30% the first year after burning with no significant reduction thereafter. Communities dominated by

wheatgrasses tend to be more detrimentally affected than communities dominated by blue grama and needle and thread.

Where fire is an appropriate management tool, the major benefits of prescribed burning in grasslands are to control undesirable shrubs and trees, burn litter, increase herbage yields, increase utilization of coarse grasses, increase availability of forage, improve wildlife habitat, and control cool season grasses where warm-season grasses are dominant. When large amounts of litter cause stagnation in prairie sites, fire is an effective tool for increasing plant growth. Removal of litter permits soil temperatures to rise in early spring which stimulates nitrification by bacteria. The high population of soil bacteria after fire decomposes organic matter to produce additional nitrates. This sequence of events, plus optimum growing temperatures created by bare soil, allows warm-season plants to grow at an optimum rate if moisture is adequate.

The young, tender growth after fire is naturally more palatable and easily accessible to herbivores. Undesirable cool-season grasses and forbs can be reduced with spring burns. Forbs, which provide an important food source for many upland game birds, are frequently more readily available on burned areas.

Fires should not be used more frequently than every five to ten years in the western portions of the Great Plains. Long-term declines in production of grasses can result from burns that occur more frequently.

Based on this review of the role of fire in prairie

ecosystems, there is little evidence that fire can be used to alter species composition or to eliminate exotic species from a community. The greatest benefit of fire for Theodore Roosevelt National Park is to reduce the accumulation of litter and prevent stagnation of grass growth. There are other benefits as mentioned above, but these two would be the most critical in maintaining a healthy grassland system. My recommendation is that a prescribed burn be planned for each prairie site with the Park at a minimum of every ten years.

There are a number of fire ecologists in the western U.S. that could provide additional expertise for the Park if needed. The foremost authority on fire in rangeland systems is Henry Wright of the Range and Wildlife Department at Texas Tech University in Lubbock, Texas. Other contacts include: Arnold Kruse, U.S. Fish & Wildlife Service, Northern Prairie Research Center, Jamestown, ND; Kenneth Higgins, USFWS. South Dakota Cooperative Fish and Wildlife Research Unit, South Dakota State University, Bookings, SD; and Jerry Dodd, Range Management Department, University of Wyoming, Laramie, WY

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FORT UNION TRADING POST

NATIONAL HISTORIC SITE

SECTION D

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INTRODUCTION

A site visit was made to Fort Union on June 12, 1992 to assess the condition of existing prairie sites and provide recommendations for restoration of grassland sites that are dominated by exotic species or previously disturbed. The Fort Union site is divided into two vegetation zones by a terrace which separates the ancient flood plain on which the Fort is located from the active flood plain of the Missouri River. Along the terrace edge and in the western portion of the active flood plain are thick growths of cottonwood (Populus deltoides), green ash (Fraxinus pennsylvanica), chokecherry (Prunus virginiana), redosier dogwood (Cornus stolonifera), and willows (Salix spp.).

The upper terrace contains the prairie sites that are in need of restoration work. Since European settlement, much of this area was heavily grazed and cultivated. As a result, smooth brome (Bromus inermis) and crested wheatgrass (Agropyron cristatum) are abundant on the site. According to Stubbendieck (1986) the prairie at Fort Union can be divided into three types. The first is called Upland Hills and is the least disturbed of the prairie sites and contains an excellent mixture of midgrasses, short grasses, and forbs. It is characteristic of the Wheatgrass-Needlegrass vegetation type. The second type is the Upland Prairie and occurs in the lower areas of the uplands. Much of this area has been farmed and few native species are present. The third type is called the Lowland Prairie and is found on the upper terrace of the

Missouri River. This type has also been placed under cultivation and native species are absent.

It is important to note that the implementation of recommendations contained in this report will require a long-term commitment of resources. The condition of the prairie at Fort Union reflects many years of either overgrazing or cultivation prior to the establishment of the historical site. Overcoming the effects of these past management practices will be a long-term process. In addition, the evaluation of any restoration activity should be judged in light of existing abiotic and biotic conditions that exist at the time that management strategies are implemented. The success of any strategy will be controlled by weather conditions, soil factors, and animal interactions.

RECOMMENDATIONS FOR RESTORATION ACTIVITIES

Site Immediately Around the Fort

The area immediately around the Fort is in need of restoration and is a high priority for future work. The site should be disked in the fall of the year to a depth of 6 to 12 inches to reduce compaction and uproot existing plants. The site should be broadcast seeded in late fall before any snow accumulation occurs. Broadcast seeding is recommended over drill seeding because stands of broadcast seeded species appear more natural that drill seeded stands, the success of broadcasting is as high as drill seeding if proper techniques are used, and broadcast seeding is less expensive than drilling because of the use of less specialized equipment.

The surface of the seedbed should be left rough prior to seeding and the broadcast seed should be lightly covered by dragging a light duty harrow or heavy chains over the seeded area. Seeding a small area, such as this, can be accomplished by using hand held cyclone broadcasters or with a cyclone broadcaster, attached to the back of a pickup or small tractor, that operates with an electric motor.

Based on limited information that I have on soil characteristics of the area, I do not recommend the use of fertilizer. The native species that we want to establish are adapted to low fertility conditions and the addition of fertilizer, especially nitrogen, will tend to promote the establishment of annuals rather than the seeded perennials.

The use of mulch will improve germination and initial plant establishment. I would recommend mulching with a weed free straw or a native hay that contained mid grass species native to the site. If mulching is done with weed-free straw or native hay, the mulch should be applied at a rate of 2 tons/acre and crimped into place to prevent loss due to high winds. A third mulching option would be the use of wood fiber hydromulch. Hydromulching must be done as a separate operation following seeding as opposed to mixing seed and mulch together. Hydromulch, if done, should be applied at a rate of 1.5 tons/acre.

The seed mixture provided in Table 1 is recommended for the site immediately surrounding the Fort. The seeding rate has been

adjusted for broadcasting and would be reduced in half if the seed were drilled.

Table 1. Seed mixture for the area immediately around the Fort

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Mandan	Agropyron smithii	2
Bluebunch wheatgrass	Agropyron spicatum	2
Thickspike wheatgrass, Critana	Agropyron dasystachyum	2
Green needlegrass, Lodorm	Stipa viridula	2
Needle and thread	Stipa comata	1
Prairie junegrass	Koeleria cristata	1
Blue grama	Bouteloua gracilis	0.5
Scarlet globemallow	Sphaeralcea coccinia	2
or		
Gooseberry globemallow	Sphaeralcea grossulariaefolia	2
White prairie clover	Petalostemum candidum	2
or		
Purple prairie clover, Kaneb	Petalostemum purpureum	2

Other Prairie Sites on the Upper Terrace

11 Acre Restored Site

The 11 acre site that has been plowed and seeded to native species must now be properly managed to reduce the annual component. The site should be mowed between 1 June and 15 July every year until the annual component is under control. Mowed material should be removed to reduce litter accumulation.

Approximately 3 to 4 years after initial stand establishment the site should be burned in the summer (mid July to late August). The use of prescribed fire should be incorporated into the management plan for all prairie sites at Fort Union and burning should occur once every 5 to 7 years. Prescribed burning will control undesirable shrubs and trees, reduce litter accumulation,

increase herbage yields, improve wildlife habitat, and stimulate greater species diversity.

Non-Restored Areas

Those prairie sites that are in need of restoration should be treated as follows. Those areas that have crested wheatgrass should be deep plowed (12 to 18 inches) once a year for two years (late spring the first year and mid summer the second year) before seeding natives. Those areas colonized only by annuals, if they exist, should be deep plowed twice during one growing season (early summer and early fall) prior to seeding natives. Those sites with smooth brome should be treated according to the procedures established at the Lostwood National Wildlife Refuge for controlling unwanted perennial grasses.

Once treatment is completed, the site should be disked to a depth of 6 to 12 inches in late fall prior to seeding. Seeding practices should follow those summarized above. The seed mixture in Table 2 is recommended for restoring all other prairie sites on the upper terrace.

The seed mixture in Table 2 includes a cover crop of Regreen, which is a synthetic hybrid between wheatgrass and wheat. This is a desirable cover crop because it does not continue to reseed itself as do small grain crops that are typically used as a cover crop for perennial species. Under good growing conditions, part of the original population of individual plants of Regreen (as much as half) will continue the second growing season and a much smaller

amount may continue in the third growing season. The use of Regreen will eliminate the need for mulch and will also serve to reduce the colonization by annual species without causing competitive exclusion of perennial seedlings. Regreen is not recommended for seeding the area immediately surrounding the

Table 2. Seed mixture for other prairie sites on the upper terrace.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Mandan	Agropyron smithii	2
Bluebunch wheatgrass	Agropyron spicatum	2
Thickspike wheatgrass, Critana	Agropyron dasystachyum	2
Green needlegrass, Lodorm	Stipa viridula	2
Needle and thread	Stipa comata	1
Prairie junegrass	Koeleria cristata	1
Blue grama	Bouteloua gracilis	0.5
Regreen	Agropyron x Triticum	8
Scarlet globemallow	Sphaeralcea coccinia	2
or		
Gooseberry globemallow	Sphaeralcea grossulariaefolia	2
White prairie clover	Petalostemum candidum	2
or		
Purple prairie clover, Kaneb	Petalostemum purpureum	2
Fringed sagewort	Artemisia frigida	0.5
Silver sagebrush	Artemisia cana	0.5
Winterfat	Ceratoides lanata	0.5

Fort because of the more unnatural appearance that Regreen presents during the first one to three years that it is present. If this visual concern is not of major consequence then Regreen could be added to the mixture in Table 1 and mulching could be eliminated as a proposed treatment.

If undesirable annuals become an important component of the restored areas then management practices should be implemented to reduce their presence. It is common for annuals to dominant restored areas the first year after seeding. However, if seeded

perennials species have also established in the understory of the annuals there is a good chance that the perennials will competitively exclude the annuals in two to three years without any human assistance. This process must be closely monitored and if the annuals are not being replaced through natural successional processes, then mowing should be implemented between 1 June and 15 July (and mowed material removed) each year that it is needed. Once the native prairie has become established, prescribed fire should be used to maintain the health of the community. As noted above, sites should be burned every 5 to 7 years depending upon climatic conditions and litter accumulation. Under wetter conditions more biomass will be produced and more litter will accumulate. These conditions will lead to more frequent burning than conditions of more limited moisture.

Inside the Fort

The open area within the walls of the Fort need to be restored with prairie species that will withstand human foot traffic. The primary limitation to establishing vegetation in this area is the restriction on disturbing the soil because of cultural resources. The best choice of plant species for this area would be blue grama. Blue grama is difficult to establish, but once in place will provide the durability that is needed along with very low maintenance requirements.

Blue grama should be broadcast seeded at 4 lbs PLS/acre and lightly raked to provide some soil coverage. The best time to seed

would be mid to late spring. To assure stand establishment, the seeded areas should be irrigated until emergence and then for an additional 20 days after emergence. This will provide the necessary moisture that blue grama seedlings need to establish adventitious roots that are critical for long-term survival. Irrigation should be applied to keep the upper 1/2 inch of soil moist until germination and emergence occurs. An irrigation schedule of every other day should be adequate, depending upon natural precipitation. Following emergence, supplemental water should be applied at a rate of approximately 1/2 inch, three times per week, for three weeks. No further irrigation should be used after the stand has become established.

Because of limited irrigation capabilities at the site it will most likely be necessary to restore only small portions inside the Fort at any one time. Once an area is completed, then another area can be seeded and irrigated until the entire area of exposed soil is restored.

River Bank of the Upper Terrace

The river bank just south of the Fort is steep and colonized by a number of exotic species. Some effort should be put forth to exclude exotics from this area and establish native species. The upper half of the bank should be sprayed with Roundup in late spring and again in late summer, if needed to kill existing vegetation. The soil on the bank should then be roughened with hand tools in late fall and broadcast seeded with native sod

forming grasses to hold the soil in place and exclude the invasion of undesirable species. The seed should be lightly covered with soil by hand raking and the site should be covered with an erosion control netting such as a light weight excelsior blanket. The seed mixture proposed for this site is presented in Table 3.

Table 3. Seed mixture for the river bank of the upper terrace.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Mandan	Agropyron smithii	7
Thickspike wheatgrass, Critana	Agropyron dasystachyum	7
Blue grama	Bouteloua gracilis	2

Management of Grassland along Lower Terrace

The grassland site along the north side of the Missouri River needs to be properly managed to maintain the health of this community. Management of this site could include burning or mowing. Burning would have more positive ecological effects than mowing and therefore would be the first choice if burning can be accomplished without damaging the riparian vegetation along the edge of the bank. Burning should be done in either spring or early fall when weather conditions are optimal. This management practice should be repeated every 5 to 7 years.

If mowing is selected over burning, this practice should be repeated every 3 to 4 years and the mowed material should be removed from the site. The best time to mow this site would be in

early fall after plants have set seed and translocated carbohydrates belowground.

CONCLUSIONS

Successful restoration at the Fort Union site will require a commitment of resources for a number of years. From my limited exposure to this site I found no remnants of a native prairie on the upper terrace. Even areas that had not been cultivated were dominated by exotic grasses. There is some leafy spurge (Euphorbia esula) on site but it appears that the spraying program that has been implemented is controlling the spread of this species.

Areas that have received some restoration activity need to be properly managed to control annuals and promote the establishment of native perennials. Once the native prairie is established on these site then prescribed fire needs to be used to maintain the health of these communities.

Those areas that are in need of restoration work will require plowing or herbicide control before native perennials are seeded. Since the collection of native seed within the boundaries of the historical site is not feasible because of the lack of seed sources, all seed that is used for restoration will come from commercial suppliers. Extreme care must be taken to assure that the seed that is purchased is adapted to the soil and climatic conditions of the site. Specific varieties have been recommended for those species that have improved cultivars adapted to the conditions of Fort Union. If a variety is not recommended then

every effort should be made to assure that the source of seed comes from soil and climatic conditions similar to Fort Union.

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WIND CAVE NATIONAL PARK

SECTION E

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INTRODUCTION

A site visit was made to Wind Cave National Park on June 15 and 16, 1992 to address issues associated with restoration activities on grassland sites within the Park. The specific issues that were discussed during my visit included the restoration of the Boland Ridge Road that is severely eroded, the establishment of permanent plots to monitor the invasion of exotic species and determine use by native ungulates, the use of fire as a management tool for grassland sites, the status of vegetation mapping in the Park, and the potential for seed collection in the Park for future restoration projects.

The following report addresses the issues listed above and provides specific recommendations for each item. It is important to note that the implementation of the recommendations contained in this report will require a long-term commitment of resources. In addition, the evaluation of any restoration activity should be judged in light of existing abiotic and biotic conditions that exist at the time that management strategies are implemented. The success of any strategy will be controlled by weather conditions, soil factors, and animal interactions.

RECOMMENDATIONS FOR RESTORATION AND MONITORING ACTIVITIES

Restoration of Boland Ridge Road

An 8/10 mile section of Boland Ridge Road has experienced severe erosion because of the steep terrain surrounding the road,

the presence of highly erosive soils, and the steep grade of the road itself. There are several problems that need to be adequately addressed for the road to be successfully restored. These include: 1) importation of fill material to cover and reduce the slope of cut banks and to fill existing gullies, 2) control of overland flow of water on the road surface, and 3) establishment of native species that will provide permanent stability for the site.

The first step in the restoration process should be to cover and if possible, reduce the slope of cut banks and fill existing gullies. This step may be the most difficult because of the limited amount of fill material that would be available within the Park. This material does not need to be topsoil and should be more resistent to erosion than the existing soil in this area.

Those cut slopes along the road that are steep (>50%) should be reduced to a 40 to 50% slope by using fill material. Using fill to reduce slope angle is preferred over additional cutting because of the additional disturbance that would be caused by this activity. After filling, the road base should be scarified or ripped to at least 12 inches to reduce any compaction and provide a more favorable seedbed.

Once gullies are filled and slopes reduced or at least covered to eliminate the exposure of these highly erosive soils, hay bales should be used to control overland flow. Bales should be placed along the top of all cut banks immediately above the disturbed cut. Bales should be secured in place with 2" x 2" wooden stakes that are at least 3 feet long. Additional bales should then be placed

perpendicular to the slope of the road and up the lower one-fourth of each cut bank. Each row of bales should be placed approximately 50 feet apart for the entire length of road segment that is subject to erosion.

The entire disturbed site should then be fertilized and seeded after the bales are in place. Nitrogen should be added at a rate of 25 lbs of total N/acre, phosphorus at a rate of 75 lbs of total P/acre, and potassium at 50 lbs of K/acre. Ideally, the fertilizer should be applied prior to scarifying the site in order to incorporate the fertilizer into the root zone. The seed mixture in Table 1 should then be broadcasted over the site and the area raked to cover the seed.

An erosion control netting, such as a light weight excelsior, should then be placed on the cut slopes to provide additional erosion protection until plant establishment takes place. The main part of the road can be mulched with straw or hay at a rate of 2 tons/acre. This material could be crimped into the soil with hand shovels in order to prevent loss of this mulch from high winds.

It is important that special care be taken in selecting a source of hay or straw bales for erosion control and mulching. If straw is used, the material should be seed free to prevent the introduction of exotic annuals. If hay is used, then it should be a native hay consisting of species native to the Park. It may be difficult to find native hay, but it would be preferred over straw because of the added species diversity that could be achieved.

Table 1. Seed Mixture for Boland Ridge Road restoration.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Mandan	Agropyron smithii	4
Green needlegrass, Lodorm	Stipa viridula	3
Little bluestem	Andropogon scoparium	2
Sideoats grama, Pierre	Bouteloua curtipendula	2
Buffalograss	Buchloe dactyloides	3
Canada wildrye	Elymus canadensis	4

Restoration work on the road should take place in the fall of the year. Seeding should occur in mid to late October or before a consistent snow cover occurs in the fall. Whenever a plant community of warm and cool season species are being established, one growth form will always predominant depending upon the season of planting. Fall seeding tends to favor cool season species and spring planting will favor warm season species. Ideally, the mixture should be split into two separate seedings to give equal opportunity for all species to establish. This approach is not practical however, especially after the site has been mulched. The best compromise position appears to be a fall planting.

Vegetation Monitoring

When conducting vegetation monitoring there are several questions that need to be addressed in order to establish a monitoring program that best serves the needs of the Park. The first question that should be asked is what is the objective of monitoring? In this case, monitoring will be done for at least two reasons. The first is to establish a baseline to determine the current condition of various grassland sites within the Park.

Monitoring over time can then be used to quantify changes that are taking place over time. Such questions as: 1) is the habitat of exotic species increasing? 2) what effect are bison and elk use having on the condition of the grasslands? 3) are prairie dog colonies expanding and what effect is this having on plant species composition?

After the objectives of monitoring are determined, the next question that needs to be addressed is what criteria should be used to select sample locations? Based on the objectives noted above, sample locations should include all major grassland types or range site designations. At least two locations within each type should be selected to provide some range in plant, soil, and topographic condition. At least one prairie dog colony should be selected that is believed to have the potential to expand in area. In addition, sampling should occur within and outside existing exclosures to monitor the effect of large herbivore use. Finally, if possible, at least one site should be selected that receives only bison use (or predominantly bison use) and at least one site that receives only elk use (or predominantly elk use) to attempt to differentiate elk and bison effect on plant species composition. It may not be possible to quantify this effect with a high level of confidence without conducting a controlled study. Therefore, these sites could be eliminated from the monitoring plan.

The final question that needs to be addressed is how should the vegetation monitoring be designed and conducted? A well-conceived sampling design is a prerequisite to any monitoring

program. The choice of a sampling design is dictated, in part, by the objectives of the monitoring program, the vegetation type, the vegetation characteristics being measured, and the availability of financial and technical resources. Designs most frequently used are random sampling and permanent plots. Sampling locations within a vegetation unit may be selected at random at each measurement time, or repeated measurements may be obtained on the points selected at random the first time. If the later approach is selected, then the position of the selected points must be permanently marked on the ground by driving steel rods to facilitate exact relocation of the plots or lines.

My recommendation for establishing a monitoring program is as follows. In each vegetation unit that monitoring is needed, a minimum of four, 100 foot transects should be randomly located (if the unit is greater than 40 acres in size then one transect should be added for each additional 10 acres). If these transects are to be permanent for repeated measurements in future years, the beginning, middle, and end of the transect should be marked with a steel rod. A small portion of the rod should be exposed to facilitate relocation. A detailed description of the location of the rods must be recorded for future reference. If transects are not to be permanent, then new transect locations can be selected each year.

Once the transect is in place, a metal rod, with a sharp point, is lowered at one foot intervals to record 100 hits per transect. The rod must be lowered in a vertical line,

perpendicular to the plane of the ground surface. Whatever is first encountered by the point is recorded as a single hit. If the hit is a plant, then the specific species is recorded. If the hit is bareground, litter, or rock, then one of these is recorded. The number of hits are then tallied together. Each hit represent 1% cover. If western wheatgrass is encountered 20 times along the transect, then western wheatgrass is showing 20% canopy cover. If along the same transect, there were 25 hits of bareground and 15 hits of litter, then this would mean that there was 25% bareground and 15% of the ground surface was covered with litter.

This procedure is called a line transect and point intercept method and is commonly used in grassland communities. This method provides a fairly unbiased rapid approach to sampling vegetation that can be repeated over time without destructively sampling the vegetation. The data along each transect can be recorded in approximately 20 minutes if the one conducting the sampling is familiar with the species present. With this approach it will be possible to detect changes in the cover of individual species in 1% increments.

Line transects can be established in any grassland type or range site where the canopy cover of low growing woody species and herbaceous species needs to be measured. Quadrats (of various sizes and shapes) can also be placed along these transects to determine woody plant density or even harvested to measure aboveground production.

The line transect approach should also be used to monitor

changes around prairie dog colonies. One approach would be to stand in the center of the colony and establish compass bearings every 45°. This would establish 8 compass bearings emanating from the center of the colony. At the point that each compass bearing intersects the edge of the colony, a 100 foot transect should be permanently marked perpendicularly to the compass bearing. This will establish 8 transects at the edge of the colony. The same procedure should then be followed to establish additional sets of transects every 25 feet away from the edge of the colony, up to 100 feet (this will establish 5 sets of transects all together). These transects should be sampled as described above and should be permanent.

All transects and quadrats that may be sampled should also be photographed to provide a photographic record of changes. In fact, good photographs of permanently marked quadrats may substitute for estimating density and biomass values. The photographs should be taken from an elevated position over the quadrat to achieve a more accurate representation of the composition of the quadrat. All sampling and photography should occur at the time of year that the dominant species have reached peak production.

Use of Fire for Managing Grassland Sites

Regardless of origin, fires have always been common and widespread on prairies, especially during drought years. In semiarid areas, large prairie fires in the past usually occurred during drought years that followed one to three years of above

average precipitation, because of the abundant and continuous fuel. There are no reliable historical records of fire frequencies in the Northern Great Plains grasslands because there are no trees to carry fire scars from which to estimate fire frequency. However, it is well known that fire frequency was high because explorers and settlers were concerned about the danger of prairie fires. It is possible to extrapolate fire frequency data for grasslands from forests having grassland understories, such as ponderosa pine (Pinus ponderosa). Fire frequency in pine forests vary from 2 to 25 years. Because prairie grassland is typically of level to rolling topography, a natural fire frequency of 5 to 10 years seems reasonable.

Climate is the dominant factor controlling North American grasslands. On the eastern edge of the Great Plains the balance between forest and grassland is so delicate that a little higher water content of soil would shift the balance in favor of tree growth. Shrubs and trees have always existed as scattered individuals on grasslands and along drainageways. In the Northern Great Plains they are most abundant in the mesic edge of the northern mixed prairie. Shrubs and trees are also present on rocky breaks or heavily grazed areas where fires are least frequent. Droughts can control shrub abundance where grass is healthy, but shifts from grasslands to shrubs and trees could occur on a 100 year cycle if vegetation was controlled solely by climate. Fire seems to have restricted shrub and tree growth in the past not so

much as a single influence but in concert with other biotic and abiotic factors.

The amount of research on the effects of fire in the mixed grass prairie of the Northern Great Plains is limited. Some of the most informative papers have been published by Clarke et al. 1943, DeJong and MacDonald 1975, Hopkins et al. 1948, Launchbaugh 1964 and 1972, Coupland 1973, Rowe 1969, and Dix 1960. In general it is known that spring burning reduces grass yields 50% the first year, 15% the second year, with full recovery the third year. Fall burning decreases grass yields 30% the first year after burning with no significant reduction thereafter. Communities dominated by wheatgrasses tend to be more detrimentally affected than communities dominated by blue grama and needle and thread.

Where fire is an appropriate management tool, the major benefits of prescribed burning in grasslands are to control undesirable shrubs and trees, burn litter, increase herbage yields, increase utilization of coarse grasses, increase availability of forage, improve wildlife habitat, and control cool season grasses where warm-season grasses are dominant. When large amounts of litter cause stagnation in prairie sites, fire is an effective tool for increasing plant growth. Removal of litter permits soil temperatures to rise in early spring which stimulates nitrification by bacteria. The high population of soil bacteria after fire decomposes organic matter to produce additional nitrates. This sequence of events, plus optimum growing temperatures created by

bare soil, allows warm-season plants to grow at an optimum rate if moisture is adequate.

The young, tender growth after fire is naturally more palatable and easily accessible to herbivores. Undesirable cool-season grasses and forbs can be reduced with spring burns. Forbs, which provide an important food source for many upland game birds, are frequently more readily available on burned areas.

Fires should not be used more frequently than every five to ten years in the western portions of the Great Plains. Long-term declines in production of grasses can result from burns that occur more frequently.

Based on this review of the role of fire in prairie ecosystems, there is little evidence that fire can be used to eliminate exotic species from a community. The greatest benefit of fire for Wind Cave National Park is to reduce the accumulation of litter and prevent stagnation of grass growth. There are other benefits as mentioned above, but these two would be the most critical in maintaining a healthy grassland system. My recommendation is that a prescribed burn be planned for each prairie site with the Park at a minimum of every ten years. In addition, research should also be considered to determine if fire can be used to eliminate exotic grasses. There may be some specific combination of factors such as temperature of the burn along with season that may be effective in removing certain species.

Seed Collection

There are basically 3 approaches that can be taken to obtain seed for Wind Cave National Park. The first is to purchase seed commercially. The second is to collect seed within the Park and use this seed directly. The third option is to collect seed within the Park and use this seed in an increase program to multiply seed availability for future restoration projects.

Purchasing seed from a commercial supplier is the simplest approach and most inexpensive. Most of the dominant species that would be seeded in a restoration project are available commercially. Some of these species would have improved cultivars available that will provide some assurance that the seed being purchased will manifest certain genetic characteristics and be adapted to certain climatic and edaphic conditions. However, the majority of native species that would be needed will not be available as improved cultivars and care must therefore be exercised in purchasing this material. When purchasing seed of species without named cultivars it is essential to specify sources of seed that originate from environmental conditions similar to the conditions in which they will be planted. With this restriction, it may not always be possible to obtain the species that are needed in any one year.

The second approach provides plant materials that originate in the Park and have proven adaptability to the growing conditions found within the Park. The two primary limitations associated with this option is the fact that seed is not produced every year by

every species for which seed may be required and the amount of seed that can be collected within the Park will be somewhat limited. Seed production is subject to the vagaries of nature and natural phenomenon such as drought and insect infestations will affect seed production. Therefore, there will be years that some species will produce no seed or very limited amounts of viable seed. In those years that seed production is good, it still may not be possible to collect the quantity of seed that would be needed to seed a ten acre restoration project, for example.

The third option may be the most expensive, but is one that provides the most assurance of quantity and adaptability. Relatively small quantities of seed can be collected in the Park and increased at a plant materials center. This increased seed will produce plants that are adapted to the growing conditions in the Park and quantities can be generated to meet specific restoration needs. This option does require lead time to produce specific quantities of seed. For example, if seed is needed to restore a disturbance in 1995, then seed would need to be collected in 1992. This 1992 seed could be planted in an increase field in the fall of 1992 or the spring of 1993 and seed would be available after the second growing season which would be 1995. Under this scenario a minimum of three years lead time would be required to produce seed for a specific restoration project.

Making a decision as to which approach is best for Wind Cave National Park is difficult. Some parks have opted for the increase program in order to assure the availability of certain species in

quantities needed for a specific project. Other parks have taken every step possible to maintain genetic purity of species and ecological integrity of communities and have chosen seed collection programs and increase programs to help accomplish this goal. In Wind Cave National Park the invasion of exotic grasses is widespread and it may be very difficult to justify maintaining the genetic integrity of native species or the ecological integrity of a specific grassland community when the ecological integrity has already been violated by decades of mismanagement before the Park was ever established and genetic integrity may already be compromised with the use of plant materials that were not indigenous to the Park.

In addition, most of the dominant species that would be selected for restoration are available from commercial suppliers. This material can be purchased as improved cultivars or with restrictions with respect to geographic origin. It must be recognized that restoration efforts within this Park will never yield prairie sites that are composed of only native species or only native species that originated genetically from within the Park boundaries or even adjacent to the Park. To have this goal would be praise worthy, to achieve this goal would be unrealistic and impossible given the resources that are available.

My recommendation for sources of plant materials for future restoration projects is to purchase seed commercially for native plants with cultivars specifically adapted to the climatic, topographic, and edaphic conditions of the site in question. For

those species that are not commercially available, I would recommend contracting with seed collectors to collect seed within the Park (if species are present in large enough quantities) or within a 100 mile radius of the Park. If the quantity of seed needed for a specific project cannot be obtained by this means, then those species should be collected in smaller quantities and increased at an SCS plant materials center. Advanced planning needs to occur to assure that seed is available when required.

Those species that are likely candidates for collection include needle and thread, green needlegrass, little bluestem, big bluestem, blue grama, and Canada wildrye.

The timing of seed collection is one of the most crucial and difficult steps in the process of collecting seed. Collection of immature seeds results in low seed viability or dormancy. The danger of delaying collection is that the fruits of many plants dehisce (fall from the seedhead) very rapidly, so seeds are lost if collection is delayed.

There is no substitute for experience in judging when to collect seeds of prairie species. To start a collection program for a species with which you have no previous experience is difficult. Essentially you must investigate the phenology of the species to be collected. The principle stages of phenology that you would be interested in are flowering, seed formation, and seed maturity. Flowering is the first phenological stage of which you must be cognizant. Flowering is obvious for many species with colorful petals, sepals, and bracts; but careful attention is

required to note anthesis (shedding of pollen) with many grasses. After flowering the sequence of phenology is as follows: 1) soft-dough stage--this stage is indicated by the excretion of dough from seeds when squeezed between the thumb and forefinger; seeds collected at this stage will normally not germinate; 2) hard-dough stage--the hard-dough stage can be judged by biting the seed, once the dough stage is completed; in other words, if you cannot squash the seed between the thumb and forefinger, try biting it; once the seed is fully mature, it is usually too hard to bite; seed collection should begin with the transition from soft to hard dough; 3) maturity--maturity and seed dehiscence may occur at the same time; to make sure some seeds will be obtained, repeated collections may be necessary; collections should extend from the later part of the soft dough stage until all seeds are lost.

During the collection process a random sample of seed (400 seeds) should be sent to a seed testing laboratory to conduct a tetrazolium test to determine the viability of the seed being collected. This test can be normally completed within 48 hours and will tell you if the seed you are collecting is viable and has the potential of germinating.

Seeds of grasses can often be collected by stripping. The process consists of allowing the grass stems to collect between the fingers and the seeds to be scraped from the terminal inflorescence as your hand moves forward. Another approach with grasses is to gather the inflorescence of the plant together and cut the stem just below the seed head.

Broadleaf herbaceous species (forbs) are more difficult to collect than grasses. The seeds of many forbs can be collected by holding a tray or box under the inflorescence while shaking or flailing the mature seeds into the receptacle. Fiber glass trays used in photographic darkrooms are excellent receptacles for this purpose or flat cake pans will work. For very small forbs, the simplest method of collection may be cutting the entire plant and bagging the material in paper sacks, leaving the bags open in a dry, well ventilated place until the seeds mature. Herbaceous species with capsules (such as scarlet globemallow) or other fruits that explode, present a special problem for collection. The only way to collect seeds of this type is to carefully collect the fruits while they are immature and allow then to ripen to mesh bags. If the capsules are even touched at the right stage of maturity they will explode and the seed will be lost.

Shrub species can be collected by holding a tray or box under outstretched branches while flailing the bushes with a stick or paddle. Other species, such as sagebrush, can be stripped.

Following seed collection, the seed should be cleaned by a professional seed cleaner. SCS plant material centers have the necessary equipment and may provide this service. The only other option is to contract with commercial seed suppliers. The use of cleaned seed is mandatory in order to know both quality and quantity of the seed being planted.

Proper seed storage is a vital step in the seed collection process to guarantee viable seed. The two major concerns in

storing seed are temperature and moisture. Two rules of thumb that relate to the influence of moisture and temperature on the rapidity of seed deterioration are: 1) each 1% reduction in seed moisture doubles the life of the seed and 2) each 10°F reduction in seed temperature doubles the life of the seed.

If seed moisture content is high enough (above 30%), nondormant seed will germinate. From about 18 to 30%, heating due to microbial activity will occur if oxygen is present, resulting in rapid death of the seed. From about 10% seed moisture for oily seeds and about 13 to 18% for starchy seeds, storage fungi grow actively and destroy the seed embryo. Therefore, seed should be dried as quickly as possible to below 13% seed moisture and should be stored below this moisture content at all times. However, drying to below 4 to 5% seed moisture will also result in more rapid deterioration than if seed is dried to a range of 6 to 10%.

To dry seeds, the relative humidity of the air must be below the equilibrium with seed moisture so there will be a moisture gradient from the seed to the air. Seeds can be dried in heated or unheated air but in most cases unheated air will not be effective in producing a safe moisture content. Therefore, heated air is most commonly used with an air temperature not to exceed 100°F. There should be good air flow around the seed and it is critical not to dry seed too rapidly because if the moisture gradient from the seed surface is steeper than the moisture gradient from the interior of the seed to the seed surface, the surface will dry

rapidly and cause cracking of the tissue or even shrink the outer cells and create a layer impervious to moisture.

The rule of thumb for temperature is applicable down to at least 32°F. If seed moisture is below 14%, no ice crystals form below the temperature at which seed freezes, so storage of dry seed at subfreezing temperatures should improve longevity. Unfortunately, most storage units that produce subfreezing temperatures also have high humidity and seeds will take on moisture over time unless the seed is placed in moisture-proof containers.

After seeds are dried to the desired moisture content, they must be kept at this level or the cost and benefit of drying the seed are lost. Maintaining the seed in a dry condition can be done in three different ways: 1) the storage unit is made moisture proof and has dehumidification equipment, 2) the seeds may be stored in moisture-proof containers, or 3) the seeds may be placed in gasketed containers with dry indicator silica gel (2 lbs of gel for every 10 pounds of seed). If drying and storage are done correctly, most of the seeds that would be used at Wind Cave would maintain good viability for several years at a minimum.

Vegetation Mapping

The development of an accurate vegetation map is a critical step to help define the natural resource base and establish effective management plans for the various vegetation types and land units in the Park. After studying the vegetation map produced

for the Park by Vicente Soares, I have some strong reservations about its usefulness. The map was developed using Landsat Thematic Mapper data, using an image collected from Landsat-5 on October 10, 1989. In the initial mapping process a total of 50 cover classes were identified which were then reduced to 11 categories.

The specific limitations that I see associated with the cover map that has been generated are as follows: 1) it is not possible for me to evaluate the test procedure that was used to determine the accuracy of the classification, however, the overall classification accuracy has been reported to be 71%; in other words there may be, at a minimum, approximately 30% of the pixels misclassified; 2) it has been reported that most of the misclassifications occur in similar cover types; this is misleading however, because a misclassification of grass versus grass/prairie dog cannot be considered to be a minor error in classifying; it also appears that there may be misclassifications associated with roads and high density ponderosa pine areas; these misclassifications limit the value of the map; 3) the map is based on an image collected in October; this late fall date is inadequate for differentiating plant community types that have a large herbaceous component and 4) the level of ground validation that was done in the field was limited and adds further concern about the accuracy of the map.

Overall I am concern about the mapping effort to date and believe that some accountability should be called for with respect to the accuracy and usefulness of the existing vegetation map. It

is possible that additional field validation may correct existing limitations and improve the quality of this product.

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DEVILS TOWER NATIONAL MONUMENT

SECTION F

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INTRODUCTION

A site visit was made to Devils Tower National Monument on July 1 and 2, 1992 to assess the condition of existing prairie sites and provide recommendations for managing these prairies to restore native species. The report also includes recommendations for controlling exotic species, collecting and storing native seed, establishing cuttings of peachleaf willow (Salix amygdaloides), and monitoring to determine the success of restoration activities.

As reported by Stubbendieck (1986), the prairie at Devils Tower is surrounded by ponderosa pine (Pinus ponderosa) forests with some prairie sites existing as savannahs with open stands of ponderosa pine. The prairie vegetation at Devils Tower is unique among most National Parks, Monuments, and Historic Sites in that domestic animal use has been limited in the past and many native species are present in healthy stands. However, fire suppression over the past 60 years has resulted in an increase in woody species and a corresponding decrease in native prairie species.

Leafy spurge (Euphorbia esula) has invaded several areas in the Monument and attempts to eliminate this species or control its spread have resulted in mixed responses. Invasion by Canada thistle (Cirsium arvense) has also occurred in the Monument and it appears that control practices have been more effective than with leafy spurge.

It is important to note that the implementation of recommendations contained in this report will require a long-term

commitment of resources. In addition, the evaluation of any restoration activity should be judged in light of existing abiotic and biotic conditions that exist at the time that management strategies are implemented. The success of any strategy will be controlled by weather conditions, soil factors, and animal interactions.

In several instances prescribed fire is proposed as a management practice to control exotics and stimulated the growth of native species. Details for prescribed burning are not provided in this document and should be established by a fire ecologist that is familiar with the ecology of Devil's Tower

RECOMMENDATIONS FOR RESTORATION ACTIVITIES

Prairie to the West of the Residential Area

This site has a history of disturbance associated with haying and the presence of a number of buildings that were removed in the 1960s. Because of past disturbance, the site has a great diversity of species that range from annual exotics to late seral perennial grasses. There are excellent patches of needle and thread (Stipa comata), green needlegrass (Stipa viridula), and Louisiana sagewort (Artemisia ludoviciana). However the majority of the site is dominated by Japanese brome (Bromus japonicus), smooth brome (Bromus inermis), Kentucky bluegrass (Poa pratensis), and crested wheatgrass (Agropyron cristatum). In addition, leafy spurge, common houndstongue (Cyncglossum officinale), and pennycress

(Thlaspi arvense) are present and considered to be noxious weeds that should be controlled.

Developing a management plan for this site is difficult because there are a number of native perennials present (e.g. western wheatgrass (Agropyron smithii), common yarrow (Achillea millefolium), scarlet globemallow (Sphaeralcea coccinia), in addition to those species noted above) that should be preserved if possible. What complicates the management strategy for this site is the large number of exotic species that should be removed to provide an opportunity for the native species to increase.

In order to achieve the most complete restoration for this site, my recommendation is to plow the area and re-establish a new community. The use of prescribed fire may be an alternative, but many exotic species will remain and the increase in native perennials would not be great enough to justify the treatment. In light of this, the site should be deep plowed (12 to 18 inches) to kill existing vegetation and bury the seed bank. Plowing should be done for two years (late spring the first year and mid summer the second year) before seeding natives.

Once plowing is completed, the site should be disked to a depth of 6 to 12 inches in late fall prior to seeding. The site should be broadcast seeded in late fall before any snow accumulation occurs. Broadcast seeding is recommended over drill seeding because stands of broadcast seeded species appear more natural than drill seeded stands, the success of broadcasting is as high as drill seeding if proper techniques are used, and broadcast

seeding is less expensive than drilling because of the use of less specialized equipment.

The surface of the seedbed should be left rough prior to seeding and the broadcast seed should be lightly covered by dragging a light duty harrow or heavy chains over the seeded area. Seeding can be accomplished by using a cyclone broadcaster, attached to the back of a pickup or small tractor, that operates with an electric motor.

Based on limited information that I have on soil characteristics of the area, I do not recommend the use of fertilizer. The native species that we want to establish are adapted to low fertility conditions and the addition of fertilizer, especially nitrogen, will tend to promote the establishment of annuals rather than the seeded perennials.

The seed mixture in Table 1 is recommended for this site. This mixture includes a cover crop of Regreen, which is a synthetic hybrid between wheatgrass and wheat. This is a desirable cover crop because it does not continue to reseed itself as do small grain crops that are typically used as a cover crop for perennial species. Under good growing conditions, part of the population of Regreen (as much as half) will continue the second growing season and a much smaller amount may continue in the third growing season. The use of Regreen should reduce the colonization by annual species.

If undesirable annuals become an important component of the restored areas then management practices should be implemented to

reduce their presence. It is common for annuals to dominant restored areas the first year after seeding. However, if seeded perennials species have also established in the understory of the annuals there is a good chance that the perennials will competitively exclude the annuals in two to three years without any human assistance. This process must be closely monitored and if the annuals are not being replaced through natural successional processes, then mowing should be implemented in late spring, of each year that it is needed, before the perennial species begin to produce an inflorescence. Once the native prairie has become established, prescribed fire should be used to maintain the health of the community. A specialist in fire ecology should be contacted to provide detailed information for developing specific prescriptions for the Park.

It is possible that certain exotics, such as leafy spurge and houndstongue will re-establish following reseeding. If this occurs, spot treatment with Tordon and 2,4-D will be necessary to control their establishment.

Table 1. Seed mixture for site west of residential area.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Rosana	Agropyron smithii	3
Green needlegrass, Lodorm	Stipa viridula	3
Needle and thread	Stipa comata	1
Big bluestem	Andropogon gerardi	2
Little bluestem	Andropogon scoparius	2
Junegrass	Koeleria macrantha	1
Blue grama	Bouteloua gracilis	0.5
Regreen	Agropyron x Triticum	8
Common yarrow	Achillea millefolium	0.5
Scarlet globemallow	Sphaeralcea coccinia	2
Louisiana sagewort	Artemisia ludoviciana	1

Prairie Dog Town

The vegetation in the prairie dog town is representative of a disturbed condition and therefore characteristic of most prairie dog colonies. The dominant native species include red threeawn (Aristida longiseta), scarlet globemallow, and fringed sagewort (Artemisia frigida). Other natives that are dispersed throughout the site include yarrow, Louisiana sagewort, hoods phlox (Phlox hoodii), and woods rose (Rosa woodsi). A large number of exotics are also present and some of the more common species include sweetclover (Melilotus officinalis), several species in the mustard family, cheatgrass (Bromus tectorum), smooth brome, western ragweed (Ambrosia psilostachya), pennycress (Thlaspi arvense), and hornseed buttercup (Ranunculus testiculatus).

This site is the most difficult one to address of all the prairie sites within the Monument. The condition of the prairie is reflective of a disturbed condition which is characteristic of most, if not all, prairie dog towns. An objective of replacing the current species with late seral grasses and forbs would be unrealistic because their presence on this site would be short term. Fortunately, there is a relatively good native perennial component present that can be used as a starting point.

My recommendation for this site is to use mowing as a method to reduce annuals and increase the amount of perennials. Unfortunately, some of these perennials will continue to be exotic species such as smooth brome. Mowing should be done in late spring

or early summer before the annual species go to seed. This practice should continue once every year for at least 5 years and then once every 5 years after the initial 5 year period. The use of herbicides is not a reasonable option for this site but burning may be a possibility. The use of fire to control exotics and enhance native plant growth should be explored in the future as to its potential effect on both the plant community and the prairie dog population. Some experimental burning is recommended to determine the specific response of exotic species to fire in this area.

Sagebrush Grassland

This area is divided by the entrance road and the condition of the plant community north and south of the road is somewhat different. The area north of the road is dominated by silver sagebrush (Artemisia cana), Louisiana sagewort, smooth brome and what appeared to be a fescue species that I was not able to identify. Other species included Kentucky bluegrass, needle and thread, green needlegrass, cheatgrass, Japanese brome, crested wheatgrass, fringed sagewort, and leafy spurge. The area immediately south of the road has a similar species mixture as the north area, but has larger amounts of Japanese brome, needle and thread and snowberry (Symphoricarpos albus).

The management options for these two areas are limited. Spraying would have a negative impact on silver sagebrush but spring burning to control exotics has been shown to result in low

mortality of silver sagebrush when soil moisture conditions are good (White and Currie 1983). However, the use of fire to control Japanese brome has only shown short-term effects (Whisenant and Uresk 1990). There are no simple solutions for exotic control on these sites. Herbicides can be applied by wicking, which would be effective in a shrub community, but the technique is labor intensive. However, since these sagebrush sites are relatively small, wicking may be a viable approach for weed control.

If the attempts of controlling exotics and increasing perennial natives is not successful, then a more dramatic approach, such as plowing and reseeding should be considered. This approach should be preceded with a burn to remove live and dead vegetation and then plowed to improve the kill of existing species and to bury the seed bank. The entire area should be treated in this fashion because of the difficulty of trying to plow soil around existing shrubs. The area should then be broadcast seeded to the seed mixture in Table 1 with the addition of silver sagebrush at one half pound of pure live seed per acre and snowberry at one pound of pure live seed per acre.

Further south of the road is an old riverbed that is dominated by Kentucky bluegrass. The management of this area should include prescribed fire and continued biological control of leafy spurge. The use of fire as a management practice should follow the Devils Tower Fire Management Plan drafted in 1990. South of this area is the cottonwood site that has a mix of native and exotic species including needle and thread, western wheatgrass, silver sagebrush,

Louisiana sagewort, cheatgrass, Japanese brome, pennycress, mullein (Verbascum thapsus), and leafy spurge. This area was improperly managed in the 1980s through the misuse of Tordon on leafy spurge. The cottonwood trees were killed and it is possible that the soil has been chemically altered. Data on soil chemical properties and the status of the seed bank should be collected before any management plan is implemented on this site. If the results from these tests show that native seed is viable and that the soil will not inhibit seedling establishment, then the site should be managed with prescribed fire. However, if the soil and seed bank data indicate a problem, then other action will be needed depending upon the results of this testing.

Joyner Ridge Prairie Site

The condition of the Joyner Ridge prairie site is excellent. The dominant species include western wheatgrass, Kentucky bluegrass, green needlegrass, needle and thread, little and big bluestem, junegrass, hairy brome (Bromus commutatus) fringed sagewort, Louisiana sagewort, field chickweed (Cerastium arvense), yarrow, and a Carex spp.

There are several exotic species present on this site, but Kentucky bluegrass and hairy brome are the most abundant. The removal of these two species would create a showcase prairie site for Devils Tower. The best management approach for this area is prescribed fire. The use of fire will maintain the health of this community and may reduce the presence of exotics over time. The

fire history study in the Monument indicated that the return time for fire is about 20 years. If this is correct, then this prairie site should be burned once every 20 years. However, to accelerate the restoration process, I would recommend that the site be burned on a ten year rotation during the first 20 years and then establish a 20 year cycle.

Northeast Prairie Site

This prairie site has a greater composition of exotic species than the Joyner Ridge site. The most abundant species in this area include big and little bluestem, western wheatgrass, needle and thread, Kentucky bluegrass, Carex spp., green needlegrass, junegrass, sideoats grama (Bouteloua curtipendula), plains milkweed (Asclepias pumila), field chickweed, pussytoes (Antennaria spp.), lewis flax (Linum lewisii), hoods phlox, yarrow, milkvetch (Astragalus spp.), western ragweed, purple prairie clover (Petalostemon purpureum), leafy spurge, wavyleaf thistle (Cirsium undulatum), fringed sagewort, and Louisiana sagewort.

This site should be treated in the same manner as the Joyner Ridge site. Prescribed fire is the best management practice to reduce the accumulation of litter in this area, improve the health of the community, and reduce the presence of annual and exotic species. The site should be burned twice over the next 20 years and then on a 20 year cycle. In addition, control of leafy spurge should continue because of the potential that this species has to increase its range and exclude native species. The treatment of

leafy spurge in this community, and all others, should be accompanied by seeding of native grasses to fill in the open patch and reduce invasion by early seral species or the return of leafy spurge. The use of Regreen should not be included in these open patch seedings.

Southwest Prairie Site

Past use and management of this area has resulted in three distinct communities. The southern most one-third of this area is dominated by needle and thread. The middle one-third is dominated by Kentucky bluegrass and the northern third of this site is dominated by smooth brome and slender wheatgrass (Agropyron trachycaulum). The areas dominated by Kentucky bluegrass and smooth brome should be plowed and seeded. The same recommendations made for the site west of the residential area would hold for this site. The same species mixture should be used and all plowing and disking manipulations should be followed.

The area dominated by needle and thread should be burned in the near future and placed on a 20 year fire cycle. This should be an adequate treatment to maintain the site in a healthy condition. At some future data, in approximately 20 years, the entire prairie site can be burned as one block of land. Once this is accomplished, the entire area can be placed on a 20 year cycle for prescribed burning.

Monitoring to Determine Restoration Success

When conducting vegetation monitoring there are at least two major questions that need to be addressed in order to establish a monitoring program that best serves the needs of the park. The first question that should be asked is what is the objective of monitoring? At Devils Tower, the primary purpose of monitoring is to establish baseline conditions (e.g. plant species composition and cover prior to burning) and then to determine changes that occur over time as the plant community responds to the treatment or management practice.

The next question that needs to be addressed is how should the vegetation monitoring be designed and conducted? A well-conceived sampling design is a prerequisite to any monitoring program. The choice of a sampling design is dictated, in part, by the objectives of the monitoring program, the vegetation type, the vegetation characteristics being measured, and the availability of financial and technical resources. Designs most frequently used are random sampling and permanent plots. Sampling locations within a vegetation unit may be selected at random at each measurement time, or repeated measurements may be obtained on the points selected at random the first time. If the later approach is selected, then the position of the selected points must be permanently marked on the ground by driving steel rods to facilitate exact relocation of the plots or lines.

My recommendation for establishing a monitoring program is as follows. In each prairie site a minimum number of transects should

be established based on the size and homogeneity of the area. The prairie dog town should have a minimum of 5, 100 meter long transects east of the road and 2 transects west of the road. The area west of residential housing should have a minimum of 5 transects. The sagebrush grassland site should have at least 2 transects north of the road, 1 transect immediately south of the road, 1 transect in the old river bed, and 4 transects in the cottonwood area. The Joyner Ridge and northeast prairie sites should have a minimum of 8 transects each and the southwest prairie site should have at least 2 transects in each of the three plant community types. If these transects are to be permanent for repeated measurements in future years, the beginning, middle, and end of the transect should be marked with a steel rod. A small portion of the rod should be exposed to facilitate relocation. A detailed description of the location of the rods must be recorded for future reference. If transects are not to be permanent, then new transect locations can be randomly selected each year.

Once the transect is in place, a metal pin, with a sharp point, is lowered at one meter intervals to record 100 hits per transect. The pin must be lowered in a vertical line, perpendicular to the plane of the ground surface. A point frame is recommended to ensure that a 90° angle is maintained with the ground for each sample point. However, it is recommended that a single point be taken at each meter interval to reduce time and also because single points typically require one-third as many points as required when groups of pins are use.

Whatever is first encountered by the pin is recorded as a single hit. If the hit is a plant, then the specific species is recorded. If the hit is bareground, litter, or rock, then one of these is recorded. The number of hits are then tallied together. Each hit represent 1% cover. If needle and thread is encountered 20 times along the transect, then needle and thread is showing 20% canopy cover. If along the same transect, there were 25 hits of bareground and 15 hits of litter, then this would mean that there was 25% bareground and 15% of the ground surface was covered with litter.

This procedure is called a line transect and point intercept method and is commonly used in grassland communities. This method provides a fairly unbiased rapid approach to sampling vegetation that can be repeated over time without destructively sampling the vegetation. The data along each transect can be recorded in approximately 20 minutes if the one conducting the sampling is familiar with the species present. With this approach it will be possible to detect changes in the cover of individual species in 1% increments.

Line transects can be established in any grassland type or range site where the canopy cover of low growing woody species and herbaceous species needs to be measured. Quadrats (of various sizes and shapes) can also be placed along these transects to determine woody plant density or even harvested to measure aboveground production.

All transects and quadrats that may be sampled should also be

photographed to provide a photographic record of changes. In fact, good photographs of permanently marked quadrats may substitute for estimating density and biomass values. The photographs (prints) should be taken from an elevated position over the quadrat to achieve a more accurate representation of the composition of the quadrat. All sampling and photography should occur at the time of year that the dominant species have reached peak production.

Seed Collection

Those species that are likely candidates for collection in Devils Tower include needle and thread, green needlegrass, little bluestem, big bluestem, western wheatgrass, junegrass, yarrow, Louisiana sagewort, and fringed sagewort.

The timing of seed collection is one of the most crucial and difficult steps in the process of collecting seed. Collection of immature seeds results in low seed viability or dormancy. The danger of delaying collection is that the fruits of many plants dehisce (fall from the seed head) very rapidly, so seeds are lost if collection is delayed.

There is no substitute for experience in judging when to collect seeds of prairie species. To start a collection program for a species with which you have no previous experience is difficult. Essentially you must investigate the phenology of the species to be collected. The principle stages of phenology that you would be interested in are flowering, seed formation, and seed maturity. Flowering is the first phenological stage of which you

must be cognizant. Flowering is obvious for many species with colorful petals, sepals, and bracts; but careful attention is required to note anthesis (shedding of pollen) with many grasses. After flowering the sequence of phenology is as follows: 1) soft-dough stage--this stage is indicated by the excretion of dough from seeds when squeezed between the thumb and forefinger; seeds collected at this stage will normally not germinate; 2) hard-dough stage--the hard-dough stage can be judged by biting the seed, once the dough stage is completed; in other words, if you cannot squash the seed between the thumb and forefinger, try biting it; once the seed is fully mature, it is usually too hard to bite; seed collection should begin with the transition from soft to hard dough; 3) maturity--maturity and seed dehiscence may occur at the same time; to make sure some seeds will be obtained, repeated collections may be necessary; collections should extend from the later part of the soft dough stage until all seeds are lost.

During the collection process a random sample of seed (400 seeds) should be sent to a seed testing laboratory to conduct a tetrazolium test to determine the viability of the seed being collected. This test can be normally completed within 48 hours and will tell you if the seed you are collecting is viable and has the potential of germinating.

Seeds of grasses can often be collected by stripping. The process consists of allowing the grass stems to collect between the fingers and the seeds to be scraped from the terminal inflorescence as your hand moves forward. Another approach with grasses is to

gather the inflorescence of the plant together and cut the stem just below the seed head.

Broadleaf herbaceous species (forbs) are more difficult to collect than grasses. The seeds of many forbs can be collected by holding a tray or box under the inflorescence while shaking or flailing the mature seeds into the receptacle. Fiber glass trays used in photographic darkrooms are excellent receptacles for this purpose or flat cake pans will work. For very small forbs, the simplest method of collection may be cutting the entire plant and bagging the material in paper sacks, leaving the bags open in a dry, well ventilated place until the seeds mature. Herbaceous species with capsules (such as scarlet globemallow) or other fruits that explode, present a special problem for collection. The only way to collect seeds of this type is to carefully collect the fruits while they are immature and allow then to ripen in mesh bags. If the capsules are even touched at the right stage of maturity they will explode and the seed will be lost.

Shrub species can be collected by holding a tray or box under outstretched branches while flailing the bushes with a stick or paddle. Other species, such as sagebrush, can be stripped.

Following seed collection, the seed should be cleaned by a professional seed cleaner. SCS plant material centers have the necessary equipment and may provide this service (SCS Plant Materials Center, Route 1, Box 119, Bridger, Montana 59014 and Environmental Plant Center, P.O. Box 448, Meeker, Colorado 81641). The only other option is to contract with commercial seed

suppliers. The use of cleaned seed is mandatory in order to know both quality and quantity of the seed being planted.

Proper seed storage is a vital step in the seed collection process to guarantee viable seed. The two major concerns in storing seed are temperature and moisture. Two rules of thumb that relate to the influence of moisture and temperature on the rapidity of seed deterioration are: 1) each 1% reduction in seed moisture doubles the life of the seed and 2) each 10°F reduction in seed temperature doubles the life of the seed.

If seed moisture content is high enough (above 30%), nondormant seed will germinate. From about 18 to 30%, heating due to microbial activity will occur if oxygen is present, resulting in rapid death of the seed. From about 10% seed moisture for oily seeds and about 13 to 18% for starchy seeds, storage fungi grow actively and destroy the seed embryo. Therefore, seed should be dried as quickly as possible to below 13% seed moisture and should be stored below this moisture content at all times. However, drying to below 4 to 5% seed moisture will also result in more rapid deterioration than if seed is dried to a range of 6 to 10%.

To dry seeds, the relative humidity of the air must be below the equilibrium with seed moisture so there will be a moisture gradient from the seed to the air. Seeds can be dried in heated or unheated air but in most cases unheated air will not be effective in producing a safe moisture content. Therefore, heated air is most commonly used with an air temperature not to exceed 100°F. There should be good air flow around the seed and it is critical

not to dry seed too rapidly because if the moisture gradient from the seed surface is steeper than the moisture gradient from the interior of the seed to the seed surface, the surface will dry rapidly and cause cracking of the tissue or even shrink the outer cells and create a layer impervious to moisture.

The rule of thumb for temperature is applicable down to at least 32°F. If seed moisture is below 14%, no ice crystals form below the temperature at which seed freezes, so storage of dry seed at subfreezing temperatures should improve longevity. Unfortunately, most storage units that produce subfreezing temperatures also have high humidity and seeds will take on moisture over time unless the seed is placed in moisture-proof containers.

After seeds are dried to the desired moisture content, they must be kept at this level or the cost and benefit of drying the seed are lost. Maintaining the seed in a dry condition can be done in three different ways: 1) the storage unit is made moisture proof and has dehumidification equipment, 2) the seeds may be stored in moisture-proof containers, or 3) the seeds may be placed in gasketed containers with dry indicator silica gel (2 lbs of gel for every 10 pounds of seed). If drying and storage are done correctly, most of the seeds that would be used at Devils Tower would maintain good viability for at least 5 years.

Establishing Cuttings for Peachleaf Willow

Softwood cuttings of peachleaf willow should be used because

they generally root easier than any other type of cutting. This type of cutting is always made with the leaves attached and must therefore be handled carefully to prevent drying and be rooted under conditions which will avoid excessive water loss from the leaves. Temperature should be maintained during rooting at 75 to 80°F at the base and 70°F at the leaves. These cuttings should produce roots in 2 to 4 weeks.

It is important in making softwood cuttings to obtain the proper type of cutting material from the parent plant. Extremely fast growing, soft shoots are not desirable because they deteriorate before rooting can occur. On the other extreme, older woody stems are slow to root or may drop their leaves and not root. The best cutting material has some degree of flexibility but is mature enough to break when bent sharply.

Cuttings should be about 5 inches long with 2 or more nodes. The basal cut should be made just below a node. The leaves on the lower portion of the cutting should be removed, with those on the upper part retained. The cutting material is best gathered in the early part of the day and should be kept moist and cool at all times by wrapping in damp clean burlap or placing in large polyethylene bags. Laying the cutting material in the sun for even a few minutes will cause serious damage and must be avoided.

The percentage of the cuttings that will root and the quality of the root system formed will be greatly influenced by the rooting media used. I would recommend that you root your cuttings in a sand/peat moss mixture (2 parts sand to 1 part peat moss). The

sand should be fine enough to retain some moisture around the cuttings, yet coarse enough to allow water to drain freely through it. Cuttings should also be treated with a synthetic root promoting chemical to stimulate adventitious root development. Indolebutyric acid is probably the best material for general use, because it is nontoxic over a wide concentration range and is effective in promoting rooting of a large number of plant species.

The cuttings should be rooted in raised frames that are allowed to drain. The frames should be deep enough so that about 4 inches of rooting medium can be used. The rooting medium should be watered thoroughly before the cuttings are inserted and a constant water content maintained throughout the rooting process. Finally, as a precaution against fungus infection, it may be advisable to give the cutting material a dip in a fungicidal preparation, such as benomyl (3 oz/gal) after the cuttings are made.

Most the these recommendations come from standard plant propagation techniques used in the nursery business. These approaches have been successfully used here at Colorado State in rooting a variety of cuttings including a number of willow species such as peachleaf willow.

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FOSSIL BUTTE NATIONAL MONUMENT

SECTION G

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INTRODUCTION

A site visit was made to Fossil Butte National Monument on June 25, 1992 to address issues associated with ongoing restoration activities. This visit was preceded by a visit to the site in June 1990 to review restoration work and provide specific recommendations to aid resource management personnel.

The specific restoration issues at Fossil Butte are associated with the utility ditch, the maintenance and shop area, the dam site, erosion control in Chicken Creek, and control of exotic species. In addition, recommendations are provided for seed collection, cleaning, and storage.

GENERAL DESCRIPTION OF THE SITE

Fossil Butte National Monument is located in Lincoln County, Wyoming. The southeastern corner of the area is about ten miles west of the city of Kemmerer. The Monument covers about 8,000 acres and in the past these lands have been used principally for rangeland and wildlife habitat. The Monument is part of the Bear River system that drains into the Great Salt Lake. Elevation ranges from 6,600 feet in the southwest corner of the area to 8,084 in the northern portion of the area. Precipitation ranges from 10 to 15 inches and increases with increasing elevation.

The historical literature indicates that the vegetation of Fossil Butte was a sagebrush steppe prior to settlement. The most recent vegetation survey was conducted in 1984 and still shows that sagebrush is the dominant vegetation type. A closer look at the

vegetation of the area reveals that the present vegetation of Fossil Butte National Monument is a complex mosaic of vegetation types.

According to the grazing impact study conducted by Mountain West Environmental Services (1984) the factors controlling the distribution of species are best understood by first observing the barren shale areas on the face of Fossil Butte. In these areas there is little if any soil development. These barren shale areas extend to the top rim of the Butte in many places. As the top is approached, the slope becomes less steep and then levels off. As the slope decreases, soil accumulation increases and vegetation establishment improves to give a grass-forb type. Proceeding to level ground, soil accumulation and depth increase and a grass type develops. Moving farther from the rim, the soil becomes deeper and a sagebrush type develops.

The other vegetation types on the Monument are controlled more by available moisture in combination with soil type. Aspen and cottonwoods are almost always below seeps and runoff areas. Mountain Shrub types dominate shallower soils near the tops of the rims or on steeper slopes. Coniferous trees are found mostly on steep north facing slopes where moisture conditions are more favorable. In lower more gradually sloping drainages below seepage areas, soil accumulates but remains too wet for sagebrush. Here Wet Meadow vegetation types can be found. Finally, in saline areas the effective moisture is largely controlled by soluble salts in the upper soil profile and salt tolerant shrubs and grasses

dominate the landscape.

The grazing impact study does not specifically identify the presence of exotic species, but an examination of the species list reveals that approximately 40 exotics can be found within the Monument. This large number may reflect a long history of over grazing in the area. A list of these species is provided in Table 3. A more detailed discussion of these species can be found in a later section of this report.

RESTORATION RECOMMENDATIONS

Utility Ditch

The utility ditch should be reseeded this fall in order to improve stand establishment along this disturbance corridor. The corridor should be harrowed to create a favorable seedbed and the entire area should be broadcast seeded with the same grass species as used previously, at a seeding rate of 10 lbs of pure live seed/acre. In addition to this grass seed mixture, big sagebrush seed should be collected along the corridor and added to the mixture at a rate of 1 lb of pure live seed/acre. Big sagebrush seed should be collected in late October or early November and a sample sent to a seed testing laboratory for a tetrazolium test to determine seed viability. Viability information is essential to gain some handle on the quality of seed that would be planted. After the area is seeded, it should be lightly harrowed to cover the seed.

Maintenance and Shop Area

During my visit in June there was no indication that the seeding that was done on this site would yield a satisfactory stand of vegetation. It is possible that during the growing season that germination and establishment of perennial species took place and that plant community development is progressing. The recommendations that follow, however, assume that the seeding failed and reseeding is necessary.

The entire area surrounding the maintenance building (other than the slope) should be disked or chisel plowed in the fall to loosen the soil and create a more favorable seedbed for broadcasting seed. The mixture in Table 1 is recommended for seeding the site surrounding the maintenance shop.

Table 1. Recommended species mixture for maintenance area.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Thickspike wheatgrass, Critana	Agropyron dasystachyum	5
Slender wheatgrass, Primar	Agropyron trachycaulum	4
Western wheatgrass, Rosana	Agropyron smithii	4
Sandberg bluegrass	Poa sandbergii	1
Indian ricegrass, Poloma	Oryzopsis hymenoides	3
Big sagebrush	Artemisia tridentata ssp. vaseyana	1
Winterfat	Ceratoides lanata	0.5

This seed mixture should be broadcast at the rate indicated and covered with soil by lightly harrowing the site following seeding. The site should then be mulched with a wood fiber hydromulch at 1,500 lbs/acre.

The slope behind the maintenance and shop area is relatively

steep, invaded by annual weeds and showing signs of water erosion. The site should be mechanically reworked to eliminate rills that have occurred and to create a weed free seedbed. The weeds that are present are producing seed and this seed is being added each year to the seed bank. It is therefore important that nitrogen fertilizer not be applied to this site during future reclamation because this will only serve to accelerate their growth next season.

Seedbed preparation should create a very rough seedbed to aid in reducing runoff and to provide more "safe sites" for seedling establishment. The site should then be broadcast seeded and the seed should be lightly covered with soil, possibly by hand raking. The suggested species mixture is provided in Table 2.

Mulching should consist of hydromulch, using wood fiber material with a tackifier added to improve adherence to the soil surface. The mulch should be applied at a rate of 1 ton/acre.

Table 2. Recommended species mixture for slope in maintenance area

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Thickspike wheatgrass, Critana	Agropyron dasystachyum	8
Slender wheatgrass, Primar	Agropyron trachycaulum	3
Western wheatgrass, Rosana	Agropyron smithii	6
Bluebunch wheatgrass	Agropyron spicatum	3
Indian ricegrass, Poloma	Oryzopsis hymenoides	4
Big sagebrush	Artemisia tridentata ssp. vaseyana	1.5
Winterfat	Ceratoides lanata	1.0

Dam Area

The pond and dam area has been revegetated and is progressive well. My only recommendation for this site is to add some species

to improve diversity. Seed from basin wildrye (Elymus cinereus) should be collected when mature and broadcast seeded in open areas within this site. The seed should be spread at a rate of about 5 to 6 seeds per square foot and raked into the soil to provide adequate seed-soil contact.

In addition to seeding basin wildrye, seedlings of snowberry (Symphoricarpos oreophilus) and big sagebrush from the surrounding undisturbed community should be used as transplants in the dam area. The number of shrubs establishing in this area is limited and could be greatly enhanced by using native shrubs as a source of transplants. The best time to transplant would be in early spring before dormancy is broken and when soil moisture conditions are favorable.

Chicken Creek

Additional stabilization work is needed in this drainage. The bottom of the drainage has a good plant cover, but the slopes in many areas are lacking in vegetation cover. On those slopes that are not too steep, thickspike wheatgrass, western wheatgrass, and slender wheatgrass should be broadcast seeded at a rate of 30 lbs/acre (10 lbs/acre for each species). The seed should be covered with soil by raking, where feasible, or through foot traffic when seeding.

The use of erosion control netting, such as excelsior, should be considered as a means of controlling erosion while a plant cover establishes. Erosion control netting is rather expensive

(approximately $2,500/acre for material alone) but may provide the erosion protection that is needed for two years while plants are becoming established. Excelsior could be used on the steeper slopes in this drainage in combination with the seeding recommendation noted above.

Exotic Species

In Table 3 is a list of exotic species that are believed to occur in the Monument. Based on the limited time that I have spent in the Monument, I would estimate that most of these species are present in low numbers and only a small subset are considered to be noxious weeds and should be aggressively controlled. Of the list of species in Table 3, Canada thistle, musk thistle, perennial sowthistle, and quackgrass are considered to be noxious weeds in Wyoming. These four species should receive priority with respect to weed control efforts in the near future.

Seed Collection

Those species that are likely candidates for collection in Fossil Butte include western wheatgrass, slender wheatgrass, bluebunch wheatgrass, Indian ricegrass, sandberg bluegrass, prairie junegrass, basin wildrye, and big sagebrush.

The timing of seed collection is one of the most crucial and difficult steps in the process of collecting seed. Collection of immature seeds results in low seed viability or dormancy. The danger of delaying collection is that the fruits of many plants

Table 3. Exotic species in Fossil Butte National Monument

Common Name	Scientific Name
Agropyron caninum	Baker wheatgrass
Agropyron repens	Quackgrass
Alyssum desertorum	Dwarf alyssum
Barbarea vulgaris	Wintercress
Bromus inermis	Smooth brome
Bromus tectorum	Cheatgrass
Capsella bursapastoris	Shepherdspurse
Cardus nutans	Musk thistle
Cirsium arvense	Canada thistle
Cirsium vulgare	Bull thistle
Chorispora tenella	Blue mustard
Descurainia sophia	Flixweed
Draba nemorsa	Woods draba
Erodium cicutarium	Redstem filaree
Gentiana amarella	Annual gentian
Hyoscyamus niger	Black henbane
Kochia scoparia	Kochia
Lactuca serriola	Prickly lettuce
Lepidium perfoliatum	Clasping pepperweed
Malva rotundifolia	Mallow
Marrubium vulgare	White horehound
Medicago sativa	Alfalfa
Melilotus officinalis	Yellow sweetclover
Phleum pratense	Timothy
Plantago major	Broadleaf plantain
Poa compressa	Canada bluegrass
Poa prantensis	Kentucky bluegrass
Rumex crispus	Curly dock
Ranunculus testiculatus	Bur bittercup
Salsola iberica	Russian thistle
Sonchus uliginosus	Perennial sowthistle
Taraxacum laevigatum	Smooth dandelion
Taraxacum officinale	Common dandelion
Thlapse arvense	Field pennycress
Tragopogon dubius	Western salsify
Veronica biloba	Bilobed speedwell

dehisce (fall from the seed head) very rapidly, so seeds are lost if collection is delayed.

There is no substitute for experience in judging when to collect seeds of prairie species. To start a collection program for a species with which you have no previous experience is difficult. Essentially you must investigate the phenology of the species to be collected. The principle stages of phenology that you would be interested in are flowering, seed formation, and seed maturity. Flowering is the first phenological stage of which you must be cognizant. Flowering is obvious for many species with colorful petals, sepals, and bracts; but careful attention is required to note anthesis (shedding of pollen) with many grasses. After flowering the sequence of phenology is as follows: 1) soft-dough stage--this stage is indicated by the excretion of dough from seeds when squeezed between the thumb and forefinger; seeds collected at this stage will normally not germinate; 2) hard-dough stage--the hard-dough stage can be judged by biting the seed, once the dough stage is completed; in other words, if you cannot squash the seed between the thumb and forefinger, try biting it; once the seed is fully mature, it is usually too hard to bite; seed collection should begin with the transition from soft to hard dough; 3) maturity--maturity and seed dehiscence may occur at the same time; to make sure some seeds will be obtained, repeated collections may be necessary; collections should extend from the later part of the soft dough stage until all seeds are lost.

During the collection process a random sample of seed (400

seeds) should be sent to a seed testing laboratory to conduct a tetrazolium test to determine the viability of the seed being collected. This test can be normally completed within 48 hours and will tell you if the seed you are collecting is viable and has the potential of germinating.

Seeds of grasses can often be collected by stripping. The process consists of allowing the grass stems to collect between the fingers and the seeds to be scraped from the terminal inflorescence as your hand moves forward. Another approach with grasses is to gather the inflorescence of the plant together and cut the stem just below the seed head.

Broadleaf herbaceous species (forbs) are more difficult to collect than grasses. The seeds of many forbs can be collected by holding a tray or box under the inflorescence while shaking or flailing the mature seeds into the receptacle. Fiber glass trays used in photographic darkrooms are excellent receptacles for this purpose or flat cake pans will work. For very small forbs, the simplest method of collection may be cutting the entire plant and bagging the material in paper sacks, leaving the bags open in a dry, well ventilated place until the seeds mature. Herbaceous species with capsules (such as scarlet globemallow) or other fruits that explode, present a special problem for collection. The only way to collect seeds of this type is to carefully collect the fruits while they are immature and allow then to ripen in mesh bags. If the capsules are even touched at the right stage of maturity they will explode and the seed will be lost.

Shrub species can be collected by holding a tray or box under outstretched branches while flailing the bushes with a stick or paddle. Other species, such as sagebrush, can be stripped.

Following seed collection, the seed should be cleaned by a professional seed cleaner. SCS plant material centers have the necessary equipment and may provide this service. The only other option is to contract with commercial seed suppliers. The use of cleaned seed is mandatory in order to know both quality and quantity of the seed being planted.

Proper seed storage is a vital step in the seed collection process to guarantee viable seed. The two major concerns in storing seed are temperature and moisture. Two rules of thumb that relate to the influence of moisture and temperature on the rapidity of seed deterioration are: 1) each 1% reduction in seed moisture doubles the life of the seed and 2) each 10°F reduction in seed temperature doubles the life of the seed.

If seed moisture content is high enough (above 30%), nondormant seed will germinate. From about 18 to 30%, heating due to microbial activity will occur if oxygen is present, resulting in rapid death of the seed. From about 10% seed moisture for oily seeds and about 13 to 18% for starchy seeds, storage fungi grow actively and destroy the seed embryo. Therefore, seed should be dried as quickly as possible to below 13% seed moisture and should be stored below this moisture content at all times. However, drying to below 4 to 5% seed moisture will also result in more rapid deterioration than if seed is dried to a range of 6 to 10%.

To dry seeds, the relative humidity of the air must be below the equilibrium with seed moisture so there will be a moisture gradient from the seed to the air. Seeds can be dried in heated or unheated air but in most cases unheated air will not be effective in producing a safe moisture content. Therefore, heated air is most commonly used with an air temperature not to exceed 100°F. There should be good air flow around the seed and it is critical not to dry seed too rapidly because if the moisture gradient from the seed surface is steeper than the moisture gradient from the interior of the seed to the seed surface, the surface will dry rapidly and cause cracking of the tissue or even shrink the outer cells and create a layer impervious to moisture.

The rule of thumb for temperature is applicable down to at least 32°F. If seed moisture is below 14%, no ice crystals form below the temperature at which seed freezes, so storage of dry seed at subfreezing temperatures should improve longevity. Unfortunately, most storage units that produce subfreezing temperatures also have high humidity and seeds will take on moisture over time unless the seed is placed in moisture-proof containers.

After seeds are dried to the desired moisture content, they must be kept at this level or the cost and benefit of drying the seed are lost. Maintaining the seed in a dry condition can be done in three different ways: 1) the storage unit is made moisture proof and has dehumidification equipment, 2) the seeds may be stored in moisture-proof containers, or 3) the seeds may be placed

in gasketed containers with dry indicator silica gel (2 lbs of gel for every 10 pounds of seed). If drying and storage are done correctly, most of the seeds that would be used at Fossil Butte would maintain good viability for several years at a minimum.

FORT LARAMIE NATIONAL HISTORIC SITE

SECTION H

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INTRODUCTION

A site visit was made to Fort Laramie National Historic Site on June 29, 1992 to assess the condition of prairie sites and to develop recommendations for restoration activities that are currently needed. The specific areas that were observed during my visit included an alfalfa field, a smooth brome pasture, the farm house area associated with the Holtzclaw Tract, the old KOA campground site, the gravel pit area, the prairie area on the south side of the Laramie River, and the potential alignment for the road into the planned visitor center. This report provides specific restoration and management recommendations for each of these areas.

BACKGROUND INFORMATION

The vegetation within the boundaries of the Fort Laramie National Historical Site represent the effects of cultivation in the recent past and grazing by domestic animals that dates back to the mid 1800s. It has been reported that the grasslands had deteriorated to such an extent that domestic grazing animals had to be moved 3 miles from the Fort to find sufficient forage by 1845. The land in the immediate vicinity of the Fort was devoid of vegetation by 1847 and prickly pear (Opuntia spp.) became a dominant species following this major perturbation. Some have proposed that prickly pear be a major component of restored grassland sites at Fort Laramie because of its prevalence in the 1800s. This would be a mistake and represent a misunderstanding of

the ecological importance of prickly pear in prairie sites in this region.

Overgrazing in the area of the Fort continued through the 1800s and into the early 1990s. The combination of overgrazing and the elimination of prairie fires allowed tree seedlings to establish and persist. After the site was acquired by the National Park Service in 1938, a reseeding program was initiated using such introduced species as smooth brome (Bromus inermis).

As a result of all of this activity, along with cultivation, the prairie sites at Fort Laramie have been severely altered. Some areas have recovered and have only small amounts of exotic species. Other areas are completely dominated by exotics with very little if any native component remaining.

RESTORATION RECOMMENDATIONS

Alfalfa Fields

During my visit I saw 2 alfalfa fields that had different plant species composition. One site had been originally planted to corn and millet and at the present time is dominated by kochia (Kochia scoparia), mustard species (Brassica spp.), sweetcolver (Melilotus officinalis), yellow salsify (Tragopogon dubius), and smooth brome. Two native perennials, western wheatgrass (Agropyron smithii) and fringed sagewort (Artemisia frigida) are beginning to colonize the area. The second alfalfa field still has a large amount of alfalfa present along with Russian thistle (Salsola iberica). There are very few native perennials in this field.

The attempts at restoring these sites have been unsuccessful to date. The amount of native species that are present is not great enough to try and save these species. Therefore, both fields should be deep plowed (a minimum of 12 inches) to kill the existing vegetation and bury the seed bank to a depth that will inhibit the establishment of exotic species from this source of seed. Ideally, seeding should take place in late fall. With this seeding schedule, the best time to plow would be in the spring of the year prior to seeding. In late summer, the sites should be disked to begin forming a more favorable seedbed and to remove any volunteer plants that may have invaded. Just prior to seeding in late October, the sites should be disked one more time and then broadcast seeded using the seed mixture in Table 1. The seed should be lightly covered with soil by dragging a harrow or similar farm implement over the seeded areas. Seed should not be covered more than 1/4 to 1/2 inch deep. Following seeding, the areas should be mulched with either a seed free straw or a weed free native hay that contained species native to the area. Mulch should be applied at a rate of 2 tons/acre and crimped into the soil to prevent loss due to high winds. Hydromulching could be used in place of straw or hay, but the cost of hydromulching will be twice as expensive. If hydromulched is used. It should be applied after seeding at a rate of 1.5 tons/acre.

Table 1. Native grasses and forbs for seeding alfalfa fields.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Arriba	Agropyron smithii	5
Needle and thread	Stipa comata	2
Blue grama	Bouteloua gracilis	2
Buffalograss	Buchloe dactyloides	3
Scarlet globemallow	Sphaeralcea coccinea	3
Purple prairie clover, Kaneb	Petalostemum purpureum	2
Fringed sagewort	Artemisia frigida	1

Smooth Brome Pasture

The smooth brome pasture occupies approximately 10 to 15 acres and is in need of complete restoration. The approach that should be taken on this site is similar to that proposed for the alfalfa fields. The primary difference is that this site should be plowed twice. It may be difficult to provide complete control of smooth brome with one plowing. Therefore, the pasture should be plowed in late spring of the first year that restoration will begin. The site should be left until mid summer of the next year and plowed a second time. After the second plowing, the site should be treated in the same manner as proposed for the alfalfa fields using the species mixture in Table 1.

Farm House Area

This area is in an early stage of secondary succession with cheatgrass (Bromus tectorum), and kochia being dominant species. In addition, to these two exotic annuals, smooth brome is common in this area but not prevalent to the extent found in the smooth brome

pasture. The treatment of this site should be somewhat different than proposed for the previously discussed areas. This site should be sprayed with Roundup in late spring and again in late summer. Four weeks following the summer herbicide application, the site should be disked to knock vegetation down and loosen the soil for seeding. The area should be seeded to the species mixture in Table 2 which consists of the same species in Table 1 with the addition of a cover crop instead of the application of mulch. This site may have more annual weed invasion than the plowed areas and the use of a cover crop should help to reduce this annual component during the first two years of plant growth. The site would therefore not be mulched following seeding but the seed must be covered as prescribed for the alfalfa fields.

The cover crop selected for this site is Regreen and represents a synthetic hybrid between wheatgrass and wheat. This is a desirable cover crop because it does not continue to reseed itself as do small grain crops that are typically used as a cover crop for perennial species. Under good growing conditions, part of the population of Regreen (as much as half) will continue the second growing season and a much smaller amount may continue in the third growing season.

Table 2. Native grasses and forbs for seeding farm house site.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Arriba	Agropyron smithii	5
Needle and thread	Stipa comata	2
Blue grama	Bouteloua gracilis	2
Buffalograss	Buchloe dactyloides	3
Regreen	Agropyron x Triticum	8
Scarlet globemallow	Sphaeralcea coccinea	3
Purple prairie clover, Kaneb	Petalostemum purpureum	2
Fringed sagewort	Artemisia frigida	1

Management of Restored Areas

Short-term

The alfalfa fields and the farm house area will need to be closely monitored during the first couple years after seeding to make sure that perennials are establishing and that exotics are not dominating. If annual forbs compose more than 25% of the relative canopy cover during early summer of the first growing season, the site should be sprayed with 2,4-D amine. If the relative cover of annual forbs is less than 25%, then no spraying should be done. Over time the perennial component should increase and the annual component decrease. Spraying should only be considered a management alternative if the annual component continues to increase in future years.

An alternative to spraying would be mowing, if there are adequate perennial species present. If 30% or more of the plants present are native perennials, but weed control is still a problem, then mowing could be considered as a alternative to spraying. The site should be mowed in late spring or early summer before the

annuals set seed to a height of about 4 to 6 inches. Mowing should continue on an annual basis until annual weeds are under control.

Long-term

The long-term management of restored prairie sites should consist of either mowing or burning. If mowing is selected, the sites should be mowed once every 5 years to a stubble height of 4 to 6 inches. Mowed material should be bailed and removed from the site. The optimum time for mowing would be in late summer after seed has matured for the dominant grass species present.

The use of fire would be a better management alternative for restored prairie sites because of the important role that fire plays in grassland systems. The major benefits of prescribed burning in grasslands are to control undesirable shrubs and trees, burn litter, increase herbage yields, increase utilization of coarse grasses, increase availability of forage, improve wildlife habitat, and control cool season grasses where warm-season grasses are dominant. When large amounts of litter cause stagnation in prairie sites, fire is an effective tool for increasing plant growth. Removal of litter permits soil temperatures to rise in early spring which stimulates nitrification by bacteria. The high population of soil bacteria after fire decomposes organic matter to produce additional nitrates. This sequence of events, plus optimum growing temperatures created by bare soil, allows warm-season plants to grow at an optimum rate if moisture is adequate.

The young, tender growth after fire is naturally more

palatable and easily accessible to herbivores. Undesirable cool-season grasses and forbs can be reduced with spring burns. Forbs, which provide an important food source for many upland game birds, are frequently more readily available on burned areas.

Fires should not be used more frequently than every five to ten years in the western portions of the Great Plains. Long-term declines in production of grasses can result from burns that occur more frequently.

Old KOA Campground Site

This site has few exotics present and can be managed by mowing or burning to keep the present stand of vegetation healthy and to promote greater species diversity in the future. If mowing is selected as the management practice, the site should be mowed every other year for a ten year period. The first year of mowing should also include raking to remove the litter that has accumulated on the site. All mowed material should also be removed to control future litter build up. Mowing should occur in late summer after seed set has occurred and mowing height should be 4 to 6 inches. After the initial ten year period, mowing should then be done once every 5 years.

An alternative to mowing is the use of prescribed burning. As stated earlier, the use of fire is the preferred management alternative because of the greater benefits that grassland ecosystems receive from burning as opposed to mowing. If burning is selected, a burning cycle of once every five to ten years,

depending upon climatic conditions and litter accumulation, should be adequate.

Gravel Pit

The former gravel pit has a good compliment of native species along with a number of exotics that should be controlled. The best management approach for this site would be to mow on an annual basis to control exotic annuals for at least 5 years. In addition, the site should be interseeded with the species mixture in Table 2. Seeding should occur in late fall after the site is lightly disked to loosen the soil surface, but not kill the existing vegetation. Seed should be broadcast over the site and lightly covered with soil by dragging a set of heavy chains over the seedbed with a tractor. This interseeding will provide greater species diversity, improve density of the existing stand, and provide additional control of annual species. The mowing schedule should be modified slightly the year after seeding. The site should not be mowed the first growing season after seeding but the mowing schedule can be resumed beginning the second growing season after seeding.

Prairie Site on South Side of Laramie River

This area is in the best condition of all the sites that I examined. There is a good mixture of native grasses and some exotic species like cheatgrass (Bromus tectorum). In addition, there is more prickly pear in this area than should exist in an undisturbed prairie site and some control of this species should

take place. The best management approach for this prairie site is to use prescribed fire as described above. This site will benefit in many ways from periodic burning, one of which will be the control of prickly pear. Research has shown that prickly pear can be reduced as much 50% by burning and nearly 100% if burning is done after treating the prickly pear with 0.5 lbs/acre of Tordon 225. Prickly pear should be treated during the summer with Tordon and the entire prairie site burned in the fall. Following this initial treatment, fire should then be used as a management tool once every 10 years.

Road to New Visitor Center

With construction of a new visitor center there will also be construction of a new road. During construction of this road, all topsoil should be saved and reapplied as soon as feasible. No fertilizer should be used during the reclamation process and all sites should be ripped or scarified to a depth of 18 to 24 inches before seeding. The surface of the seedbed should be left rough and seed should be broadcasted over the site using the mixture listed in Table 3. After broadcasting, the site should be dragged with a harrow or set of chains to bury the seed with a thin layer (1/4 to 1/2 inch) of soil. Seeding should be done in late fall and the seeded area should be hydromulched with wood fiber at a rate of 1.5 tons/acre.

Table 3. Native grasses and forbs for seeding road construction.

Common Name	Scientific Name	Seeding Rate lbs PLS/acre
Western wheatgrass, Arriba	Agropyron smithii	5
Needle and thread	Stipa comata	2
Blue grama	Bouteloua gracilis	2
Buffalograss	Buchloe dactyloides	3
Regreen	Agropyron x Triticum	8
Scarlet globemallow	Sphaeralcea coccinea	3
Purple prairie clover, Kaneb	Petalostemum purpureum	2
Fringed sagewort	Artemisia frigida	1